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JOSIAH WILLARD GIBBS[1]

By Professor CHARLES A. KRAUS

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ON the one hundredth anniversary of his birth, we are here to do honor to the memory of Josiah Willard Gibbs, the greatest physical scientist that America has produced and one of the greatest original thinkers of all time. The occurrence of genius is commonly believed to be a phenomenon of pure chance, and such it may well be so far as native talent is concerned; but talent has merely a potential value; it is fruitful only when it is properly cultivated, indeed, we may say when it is self-cultivated under favorable conditions. Genius may be assisted in this process of self-cultivation but, in all cases, genius flourishes best in an environment of complete intellectual freedom. The history of American science bears this out.

Let us review, briefly, the careers of the American men of genius who contributed to the development of physical science from Colonial times up to the last quarter of the nineteenth century. Up to 1880, America had produced five great physical scientists: Benjamin Franklin, Benjamin Thompson (Count Rumford), Joseph Henry, Henry A. Rowland and Josiah Willard Gibbs.

Franklin and Rumford were products of pre-revolutionary America; they were self-taught, having received only very meager common school education. The two men, although their lives were, in certain respects, very diverse, had much in common. Both were exceptionally versatile; both were keen observers and ready experimenters; both were of a practical and inventive turn of mind; both were keenly conscious of their social environment and both did much to advance science and learning in other ways than through their scientific contributions. Franklin was active in promoting the establishment of libraries, colleges and

[1] An address delivered in Yale University on the occasion of exercises held in commemoration of the one hundredth anniversary of the birth of Josiah Willard Gibbs.

learned societies—notably, the American Philosophical Society; Rumford founded the Royal Institution, whence came the epoch-making researches of Davy and Faraday.

Joseph Henry received his formal education, such as it was, at Albany Academy. He began his scientific work while a teacher at the Albany Academy, where he remained until 1832 when he removed to Princeton. In 1846, he resigned his professorship at Princeton to become the first secretary of the newly founded Smithsonian Institution. Henry began his researches in electromagnetism while in Albany and continued them at Princeton. He was a genius of first rank, but his work has been rather overshadowed by that of Faraday.

Henry A. Rowland prepared for college, or attempted to do so, at Newark Academy. Although a brilliant student in other subjects, he had a keen distaste for Latin which he was unable to overcome. After a final unsuccessful effort to master Latin and Greek, at Andover, and lacking the necessary knowledge of these subjects for college entrance, Rowland entered the Rensselaer Polytechnic Institute, where he remained for three years. He then spent a year in the Sheffield Scientific School, at Yale, and returning to the Rensselaer Polytechnic Institute, he received his baccalaureate degree in civil engineering from that institution in 1870. Rowland was nine years younger than Gibbs, but his scientific work was contemporaneous with that of Gibbs's. Rowland's first great undertaking was an accurate redetermination of the mechanical equivalent of heat, the first determination of which had been made by Count Rumford three quarters of a century earlier. In the field of heat, American scientists have made greater contributions than in any other branch of physical science. It might be said that Rumford began the solution of the problem of heat, and Gibbs completed it.

Gibbs entered Yale College in 1854, after preparing at the Hopkins Grammar School of New Haven. He was evidently proficient in the classical languages, since, as an undergraduate at Yale, he took prizes in Latin and gave a Latin oration on graduating. He seems to have had an equal facility in mathematics, for he likewise took prizes in that subject. After graduating from Yale, in 1858, he entered the graduate school, where, after five years, he received his doctorate in 1863. After spending the following three years as a tutor in Yale College—two in Latin and one in natural philosophy—Gibbs went abroad, spending the winter of 1866–67 in Paris; the summer and winter of 1867–8 in Berlin and the summer and winter of 1868–9 in Heidelberg. He returned to America in June, 1869, and for two years thereafter seems to have had no academic connections. In 1871 he was appointed professor of mathematical physics in Yale University, which position he held until the time of his death, on April 28, 1903.

It is an interesting fact, and it would seem a significant one, that of the five men, native of America, who achieved distinction in physical science, two were self-taught, one received his education in a small academy and a fourth in a technical school; only one was the product of one of our better American colleges. Is it that men of potential genius did not enter the numerous American colleges during the Colonial and the post-revolutionary periods or is it that the course of training which these colleges thought fit to impose upon their students unfitted them for great achievement? Is the probability not that, while men of genius in America were able to overcome the handicap of lack of means, lack of education and lack of technical training, they were not able to resist the blighting influence of eighteenth and nineteenth century scholasticism? Gibbs, alone, stands out as a notable exception. May it have been that there was something in the organization of Yale College that permitted Gibbs to cultivate his mind and to find free scope for his brilliant intellect? With his ready facility in the ancient languages and, doubtless, in other subjects as well, and with his excellent preparation, Gibbs probably found much time in which to inform himself on subjects that did not appear in the curriculum of Yale in his day. It is also a notable fact that he spent five years in the Yale graduate school, the first organization of this kind in America. Here, without doubt, Gibbs found further opportunity to follow his own bent. His experience as a tutor can hardly have been a profitable one; his mind, obviously, was not interested in the classics, and there is little doubt but that Gibbs was much more interested in the development of science than he was in teaching undergraduates. Later, when he was professor of mathematical physics, he never showed any inclination to simplify his presentation of a subject or to give introductory courses for students who were not prepared for subjects as he presented them.

During his stay abroad, Gibbs must have informed himself very widely with respect to the physical sciences and trained himself in mathematics. The records show that, while in Berlin, he attended lectures in physics and technology, under Magnus; acoustics, under Kundt; electricity and electromagnetism, optics, acoustics and capillarity, under Quincke; determinants and analysis, under Weierstrass; quadratic forms and probability calculations, under Kronecker; and least squares, under Foerster. It is not known what lectures he attended while in Heidelberg, but, judging by the lectures that he attended in Berlin, it is safe to say that he attended many lectures under the notable men who were at the University of Heidelberg at that time. These included: Professors Rummer, Cantor, Hesse and Drs. Lüroth, Weber, du Bois Raymond and Eisen-

lohr, in mathematics, and Professors Kirchhoff, Helmholtz, Bunsen, Kopp and Dr. Horstmann, in physics and chemistry.[2]

Examining the record, we see that between 1858, when he graduated from Yale College, and 1871, when he entered upon his professorship of mathematical physics in Yale University, Gibbs spent ten years in preparation for his life work, not counting the three years which he spent as tutor in Yale College. The conclusion that one may draw from this is that the preparation which our American colleges afforded men of science in the nineteenth century was not necessarily fatal to the development of their genius, provided that they were able to devote sufficient time to their training afterwards. Gibbs, fortunately, was financially independent and was, therefore, able to follow his own bent. This was not true of the great mass of men in that day, as it is not true of the great mass of men in our colleges to-day. We may well ask ourselves the question: Are our colleges quenching the genius of our outstanding students through the formal curricula that they impose upon them and through the lack of opportunity for their self-development?

By training and tradition and by the force of the environment in which he was placed, Gibbs should have developed into a typical exponent of nineteenth century scholasticism. That he did not become such was in part due to his own intellectual and financial independence and in part, without doubt, to certain favorable conditions that existed at Yale in the 1850's and 60's.

Gibbs, like Franklin and Rumford, had a strong leaning toward science, with a turn toward invention; in 1866, while still a tutor in natural philosophy in Yale College, he invented a brake for railway cars and secured a patent for the same in April of that year.[3] At about that time, also, he invented a new type of governor of a higher order of approximation to astaticism than any of its predecessors. This governor was constructed in the shops of the Sheffield Scientific School and is in the collection of the Department of Physics of Yale University.[4] Until we have come to know that Gibbs was endowed with a mind which possessed a keen appreciation of and interest in things physical and practical, his life and works remain a profound mystery. Possessing intellectual powers of the highest order, as much at home in pure mathematics as in physics and chemistry, Gibbs constantly exercised his will to direct his thoughts along lines that lay within the framework of material phenomena.

It has often been stated that Gibbs never carried out an experiment. This statement is not borne out by the facts; it is known that Gibbs constructed some apparatus in his own home.[5] According to Professor Charles S. Hastings, in his Biographical Memoir on Gibbs in the National Academy of Sciences, Gibbs carried out an optical experiment. How many other experiments he may have carried out, no one can say, for Gibbs communicated to others only the results of major investigations. Speaking of this experiment, Professor Hastings, after reviewing its general purpose, says:

> . . . the tentative explanation, however, involved the occurrence of certain phenomena in specular reflection which had never been seen or, at last, recorded. As it did not seem to him that such negative evidence was conclusive, he constructed an apparatus with his own hands so perfectly adapted to the end in view that his observations afforded the proof sought. A striking light is thrown upon the character of the great physicist by the fact that no reference to this theory, which must have cost much critical study, appears in his writings, nor is it known that anyone except the present writer ever saw the apparatus and made the experiment for which it was designed.

In the main, Gibbs depended upon experimental results available in the literature for data with which to test his theoretical investigations. That he was familiar with the literature and quick to make use of results there available is shown by examples that appear in his treatise of 1876–8, as well as in numerous subsequent papers. His chief interests were theoretical, and his physical sense was so keen that he could frame correct physical concepts with a minimum of experience with the phenomena themselves. In this Gibbs was highly exceptional; he introduced many new and exact concepts into science long before any observations relating to them had been made.

For fifty years, now, we have been hearing much and often about the manner in which American science, in general, and Yale University, in particular, failed to recognize Gibbs and his works. The explanation is

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[2] There is no certain record of what lectures Gibbs attended in Paris, but Gibbs's own copies of lists of courses offered at the Sorbonne bear pencil marks against certain courses which were probably the ones Gibbs expected to attend, and perhaps did attend up to the time of his illness while in Paris. The marked subjects are: *Astronomy,* Puiseaux; *Calculus of Probability and Mathematical Physics,* Lamé or Briot; *Physics,* P. Dessains; *Rational Mechanics,* Liouville; *Differential and Integral Calculus,* Serrer; *Chemistry,* Balard. (For the information concerning Gibbs's studies while abroad, the writer is indebted to Professor R. G. Van Name, of Yale University.)

[3] U. S. Patent No. 53,931, April 17, 1866.

[4] Charles S. Hastings, Biographical Memoirs, Nat. Acad. of Sci., 6: 375, 1909. It is interesting to note that among Gibbs's papers was found a manuscript entitled "On the Form of the Teeth of Wheels in Spur Gearing." It has been suggested that this was a copy of Gibbs's thesis for the doctorate, but this is not certain; it does, however, bear witness to Gibbs's early interest in mechanical problems.

[5] Professor Van Name reports an apparatus that Gibbs so constructed for an optical experiment, but it is not known what the nature of this experiment was.

simple: Gibbs was half a century in advance of his time and American scientists of his day were ill-prepared to comprehend the abstract philosophical results of Gibbs's theory. Much the same thing was true throughout the world; it seems that at the time of their publication, or soon thereafter, only two men comprehended the significance of Gibbs's work. One was Clerk Maxwell, who immediately called attention to the first two papers of Gibbs; in his "Theory of Heat," Maxwell incorporated a chapter dealing with the Gibbs surface. As is well known, Maxwell constructed several models of this surface with his own hands, one of which he sent to Gibbs. Maxwell also called attention to Gibbs's later paper of 1876. Had Maxwell lived, Gibbs's theory would have become known to the scientific world much earlier than it was.[6] Another physicist who early recognized the significance of Gibbs's contributions was J. D. van der Waals, Sr. He called Roozeboom's attention to the paper on heterogeneous equilibria, and this led to the development of the phase rule in the hands of Roozeboom and his associates. Van der Waals, himself, throughout his life, was active in developing the consequences of Gibbs's theory, as is evident from his admirable text with Kohnstamm, entitled "Lehrbuch der Thermodynamik," published in two parts, the first in 1908 and the second in 1912.

That Gibbs's ability was recognized at Yale University is evident from the fact that he was appointed professor of mathematical physics in 1871 before he had published a single paper. Gibbs was early recognized by his contemporaries in America, being elected to the National Academy in 1879 and awarded the Rumford Medal in 1881. It is true, however, that while Gibbs's ability was generally recognized by his American contemporaries, his scientific contributions were not understood.

How Gibbs came to interest himself in the thermodynamics is not known; that he should have done so is not surprising. The two fields of physics that engaged the attention of physicists during the greater part of the nineteenth century were electromagnetic phenomena and phenomena relating to heat. Judging by the subjects upon which he lectured during 1871–2 and 1872–3, Gibbs at that time was interested in physical optics, particularly the elastic solid theory. According to Hastings, he arrived at the conclusion that the obstacles in the way of this theory were insuperable. Later, he was a proponent of the electromagnetic theory of Maxwell at a time when many other eminent physicists were reluctant to accept it.

[6] It is of interest to note that Rowland's first paper on the magnetic circuit was not accepted for publication by American editors. Rowland sent the paper to Maxwell, who recognized its value and sent it to the *Philosophical Magazine*, where it was published immediately, Maxwell himself reading the proof in order to avoid delay. Only another genius can recognize genius.

Phenomena relating to heat were intensively cultivated by physicists from 1842 onward. The classical researches of Rumford had been forgotten for nearly half a century, when they were independently repeated and extended by Joule between the years 1837 and 1843. Mayer published his paper on the equivalence of heat and work in 1842. As early as 1824, Carnot had enunciated his celebrated principle,[7] now known as the second law of thermodynamics, but the significance of Carnot's principle was not recognized until the relation between heat and work had been clarified in the 1840's. The concept of absolute temperature was established in two papers by Sir William Thomson in 1848 and 1851. In 1851, Clausius combined the principle of Carnot with the principle of the conservation of energy, which, by then, had been well established through the experiments of Joule. Thereafter, many physicists were active in developing the elements of thermodynamics, applying the two principles—that of Carnot and that of the conservation of energy—almost exclusively to one-component systems. Clausius introduced the entropy concept in 1865. By 1870, the framework of thermodynamics had been erected and its application to one-component systems developed. The literature relating to thermodynamics was, however, in a state of confusion; concepts were not clear, physical quantities were not well defined and the mathematical manipulations were cumbersome and unsuited for the purpose of describing the thermodynamic properties of physical systems generally.

It was natural that Gibbs, who doubtless was well acquainted with the literature of his day, should have become interested in a field where it was apparent that much remained to be done. In his first two papers of 1873, he developed the methods and forged the tools that he later used in treating physical systems from a very general point of view. He introduced the entropy concept and showed that a better description of phenomena is obtained by means of the energy-entropy-volume relation than by means of the pressure-temperature-volume relation. He showed how the state of a body may be represented by means of the energy-entropy-volume surface, every point of which corresponds to a definite state of the substance. He showed how, by means of this surface, the boundary between stable and metastable states may be readily traced, as also the boundary between metastable and unstable states, and showed, moreover, how states capable of existing in equilibrium with one another may readily be derived from the surface. By means of this surface, it is possible, at a glance, to obtain a picture of all the possible states of a physical system.

The first two papers were only preliminary to the

[7] Carnot's principle states that it is impossible to transfer heat from a lower temperature to a higher without the performance of work or, otherwise, leaving compensating changes in the system or its surroundings.

third, which appeared in two parts in 1876 and 1878, respectively; in these, Gibbs treated systems comprising any number of substances—which might or might not interact with one another—existing in any number of homogeneous parts or states of aggregation.

Previous to Gibbs, the concept of reversibility, which means equilibrium at all points of a process, was clear, but the concept of equilibrium in a heterogeneous system was still vague. For very simple systems, such as water, the equilibrium conditions were recognized and James Thomson had shown that at the natural freezing point of water, three monovariant systems meet. The concept of equilibrium in a highly complex system, involving any number of component substances, had not been touched upon prior to Gibbs. Obviously, before being able to attack this general problem of equilibrium, it was necessary to have a criterion of equilibrium. Gibbs was well versed in mechanics, and it was, therefore, natural that he should seek for some general principle, similar to the principle of virtual displacements in mechanics, which might be applied to chemical systems. That he was influenced by the earlier work of Clausius seems certain, for at the head of his treatise "On the Equilibria of Heterogeneous Substances," he quotes a couplet from Clausius:

Die Energie der Welt ist konstant.
Die Entropie der Welt strebt einem Maximum zu.[8]

The statements of Clausius are physically meaningless. Gibbs formulated the underlying idea in a form such that it could be applied to real physical systems. He states the condition for equilibrium alternatively as follows:

I. For the equilibrium of any isolated system it is necessary and sufficient that in all possible variations of the state of the system which do not alter its energy, the variation of its entropy shall either vanish or be negative.

II. For the equilibrium of any isolated system it is necessary and sufficient that in all possible variations in the state of the system which do not alter its entropy, the variation of its energy shall either vanish or be positive.

We know nothing about the energy and the entropy of the universe; we have knowledge only of finite physical systems which we can place under observation and over which we have control; therefore, Gibbs limits his system to what he terms an "isolated system" and applies his criteria for equilibrium, which follow directly from the first and second laws of thermodynamics. Gibbs shows that the two criteria, as stated above, are strictly equivalent.

Having set up criteria of equilibrium, it was necessary to define the various thermodynamic quantities, particularly the energy and entropy in terms of the variables that fix the state of the system. The concept of an equation of state was not thoroughly familiar to physicists in Gibbs's day, although it is clear that, since Andrews had already carried out his classical experiments with carbon dioxide and James Thomson had already arrived at the p,v,T surface as representing the possible states of a system, it was generally understood that the state of a simple substance is determined by these three variables. Gibbs, in his earlier paper, had shown that Thomson's representation is incomplete and that certain important thermodynamic quantities may not be derived from such a surface. It was for this reason that he introduced the energy-entropy-volume surface which gives a complete description of all thermodynamic properties of a substance.

In the case of a system containing any number of substances, it was not obvious what variables fix the state of the system. Gibbs assumed (implicitly) an equation of state involving pressure, temperature and the relative amounts of the independently variable substances present. It was then necessary to derive an expression connecting the changes in energy with changes in entropy, volume and the amounts of the various substances in the different homogeneous aggregations of matter. To do this, he introduced a new concept, namely, the thermodynamic potential, which is the derivative of the energy with respect to the mass of a given component, other variables remaining constant, so that for a given homogeneous aggregation of matter, the energy is related to the variables which fix the state of the system by a differential equation of the form:

$$d\varepsilon = Tds - pdv + \mu_1 dm_1 + \mu_2 dm_2 \ . \ . \ . + \mu_n dm_n$$

where the μ's are the thermodynamic potentials of the various substances present and ε, s and v are the energy, entropy and volume, respectively, and the m's are the masses of the constituent substances. The thermodynamic potentials, μ, together with entropy and volume, are functions of the variables T, v and the masses, m_1, m_2, . . . m_n, of the constituent substances in the different aggregations of matter which comprise the system. It is understood that the masses are independently variable and that substances may be present other than those which have been chosen as independent variables; but whatever variables may be chosen, they must be independent. Gibbs next assumed that, for a heterogeneous system, the total energy of the system is made up of the sum of the energies of all the different homogeneous parts which exist in equilibrium with one another or, as he says, *coexist*. The various homogeneous aggregations of matter, each of which has a definite equation of state, he calls *phases* and two aggregations of matter, having the same equation of state, belong to the same phase. The independently variable substance he calls *components*. What particular substances are chosen as components is arbi-

[8] The energy of the universe is constant. The entropy of the universe approaches a maximum.

trary so long as they are always independent and serve to build up all the different phases of the system.

Having arrived at a means of defining the energy and entropy of the system, Gibbs proceeds to apply his criterion for equilibrium, namely, that the energy of the system shall be a minimum under the conditions that the total volume, the total entropy and the total masses of the several components of the systems remain constant. This leads to the result that equilibrium obtains in the system when the temperature of any one phase is equal to the temperature of any other, the pressure of any one phase is equal to the pressure of any other and the thermodynamic potential of any one component in any one phase is equal to the thermodynamic potential of the same component in every other phase.

The variables of the system are the temperature, the volume and the relative amounts or concentrations of the several components in all the different phases; in order that equilibrium shall be established, these variables must adjust themselves in such a way that the condition for equality of the thermodynamic potentials of the several components throughout the system is fulfilled. This condition of equality of the thermodynamic potentials of each of the several components in the different phases thus represents a multiplicity of conditions which must be satisfied by the variables; and when the number of independent conditions is equal to the number of variables, the system is completely fixed or, as we say, is *invariant*. Gibbs showed that a system will be invariant when the number of phases, r, is equal to the number of components, n, increased by two, or algebraically, when $r = n + 2$. When the number of phases is only one greater than the number of components ($r = n + 1$), one variable of the system may be fixed arbitrarily at any desired value within the physical limits of the system; such a system is said to be *monovariant*. When $r = n$, two variables may be arbitrarily fixed and the system is said to be *bivariant*.

We may illustrate the phase rule in the case of a system built up of only one substance, that is, a system of one component. Consider a system composed of pure water. Three phases (three different states of water) may coexist at a certain temperature which is an invariable property of water. We may, for example, have water vapor, liquid water and ice coexisting at the triple point, which is 0.0076° above 0° on the Centigrade scale, and at that temperature only. If the temperature is increased, ice melts and we have an equilibrium between liquid water and water vapor which may exist at a series of temperatures and pressures. If the temperature is lowered, liquid water freezes and we have a similar equilibrium between ice and water vapor; if the pressure is increased, vapor is condensed and we have an equilibrium between ice and water, the temperature diminishing with increasing pressure. At higher pressures, a new form of solid water (ice_{II}) appears and we have an invariant equilibrium between ice_{I}, ice_{II} and liquid water.

Gibbs also considered equilibria in systems in which reactions occur among various of the molecules present. He derived a relation governing the equilibrium in such systems and showed how, in the case of dilute systems, this leads to a simple relation between the concentrations of the various substances concerned in the reaction. In brief, Gibbs, from thermodynamic considerations, derived the law of mass action which had earlier been arrived at by Guldberg and Waage on the basis of kinetic considerations. He showed, moreover, how this equilibrium depends upon temperature. In the earlier chapters of his treatise, Gibbs considered external forces to be excluded from his system; later he investigated what modifications are required when external forces act. He thus investigated the action of gravitational force, of electrical forces and surface forces. Very important was his treatment of systems under the action of electrical forces; he showed, what was not then recognized, that in such systems the energy change is not equal to the work done against the external forces, but, rather, that it is equal to the sum of two terms: (1) the reversible work done against the external forces and (2) the reversible heat change which is equal to the product of the absolute temperature and the entropy. In these considerations, he anticipated Helmholtz, who arrived at much the same result in 1882. Even more important and original were Gibbs's contributions in the field of surface forces. Here Gibbs invented entirely new concepts which had never been thought of before and which have since been found indispensable in describing phenomena that occur at the boundary between two phases of multicomponent systems.

It is not possible to give an adequate picture of Gibbs's contributions in brief form. His papers on thermodynamics cover some 400 pages and are written in a highly condensed, although elegant, style. An adequate commentary on the thermodynamic theory of Gibbs would require several thousand pages.[9] Nor are Gibbs's contributions to thermodynamics his only important contributions; he was active in many other fields, particularly in vector analysis, multiple algebra and the electromagnetic theory. The most important of his other contributions, however, is his treatise on statistical mechanics, which was published in 1902. Here, as in his treatise on thermodynamics, he reduces his assumptions to the very minimum and arrives at results of the greatest generality.

The generalizations of Gibbs concerning heteroge-

[9] Compare, for example, "Commentaries on the Scientific Writings of J. Willard Gibbs," Volume I, Thermodynamics, Yale University Press, New Haven, 1936.

neous equilibria have exercised an influence upon chemistry which is second only to that of the law of the conservation of mass. Although some of the relations that follow from Gibbs's theory were subsequently discovered independently by other investigators, these were derived in a much less general manner than by Gibbs, and not infrequently they were applied when limiting assumptions (often implied) were not fulfilled and the results obtained were misleading. At the time of Gibbs, chemists concerned themselves very little with the physical properties of chemical systems; physical chemistry, as such, had not yet come into being and chemists were largely concerned with the development of organic chemistry. As physical chemistry developed during the 1880's, and later, Gibbs's work gradually came to the notice of physical chemists and the thermodynamics of Gibbs slowly replaced the earlier and less rigorous and elegant formulations. Except for certain new material and many examples, all of which fit into the framework of Gibbs's theory, modern texts on thermodynamics are essentially commentaries on Gibbs's thermodynamical theory.

Of all the relationships following from Gibbs's thermodynamical theory, the simplest and, at the same time, the most general, is the phase rule. With the aid of the phase rule, it is possible to arrive at a knowledge of the constitution of material systems and the relation of various parts of such systems to one another without destroying the systems themselves. In many respects, it is a more powerful tool than is chemical mass analysis, which is useful only if the systems in question may be resolved into their component parts without changing their nature and composition. In the case of metallic systems, for example, which are frequently very complex and the component parts of which can not be separated from one another by analytical means, the phase rule enables us to determine the composition and number of substances present and the influence which these substances have on the properties of the material in question. Take such a simple case as that of carbon steel: here we have to do with iron in its several forms, together with several kinds of solutions of carbon in iron and with free carbon. Mass analysis enables us only to determine the gross composition of the steel; with the aid of the phase rule, we can determine the different kinds of substances present, how they may be transformed into one another by change of conditions, and how the properties of the steel depend upon the various substances present and the history of the sample of steel.[10] As an example, however, carbon steel is an oversimplified case of a metallic system; modern steels are extremely complex, containing, in addition to carbon, various amounts of such elements as tungsten, molybdenum, tantalum, uranium, chromium, nickel, silicon, titanium and many others. The detailed structure of these steels has been determined with the aid of the phase rule.

What is true of the alloys of iron is true of the innumerable alloys of other metallic elements such as magnesium, aluminum, zinc, copper, tin, nickel, chromium, antimony, bismuth, platinum, gold and the like. These alloys have proved invaluable in modern industry. Except for the availability of such alloys designed to meet the needs of special conditions, modern machines, such as the automobile, the aeroplane and the streamlined railway train, would not be practical.

The phase rule finds application, also, in the ceramics industry, in the cement industry and, particularly, in the chemical industry. In the oil industry, for example, it is necessary to separate very complex liquid mixtures into various components having desirable and necessary properties. The present art of the separation of hydrocarbon oils, by distillation, by solvent extraction and by other means, is based upon the phase rule.

I have discussed the phase rule somewhat in detail, as an example, but Gibbs's theory leads to many other important consequences. The laws governing the equilibrium in reacting systems follow directly from this theory. So, also, Gibbs's theory provides a foundation for the treatment of colloidal systems. Much remains to be done in this field, but Gibbs has provided the fundamental concepts by means of which the problems of colloid chemistry may ultimately be resolved. The unravelling of the nature of living systems, which are largely colloidal in nature, involves surface phenomena that are amenable to Gibbs's theory.

Because Gibbs was a man of retiring disposition and was very much preoccupied with his important researches, he had no large circle of friends and entered into no active correspondence with other investigators. We may, therefore, be misled into undervaluing Gibbs's versatility and his ability in directions other than those which he chose to follow.[11] A paragraph from the Biographical Memoir of Josiah Willard Gibbs by Pro-

[10] The phase rule is normally applied in conjunction with other physical observations such as crystalline structure, electrical, magnetic and mechanical properties.

[11] A number of statements in the literature relating to Gibbs are without foundation. Such a one is the statement that he was a student of Clausius. Clausius was at Wurtzburg when Gibbs was at Heidelberg and there is nothing to indicate that Clausius and Gibbs ever met. Another statement that gives quite an erroneous impression of Gibbs's character and of his home relations is to the effect that Gibbs was pressed into service by his sister to drive the family carriage because her husband, who was librarian at Yale, was too busy to do this. The truth of the matter is that Gibbs took very little exercise, walking only between his home and his office in the Sloane Laboratory. The members of his family, therefore, took advantage of every opportunity to induce Professor Gibbs to get out of doors. He rather enjoyed driving the family carriage and occasionally rode horseback as well.

fessor Hastings throws much light on this situation. He writes:

> It will surprise no reader of the numerous biographical notes concerning Professor Gibbs to learn that a man of so judicial a temperament was a very successful man of affairs. Happily for science, his position in the University was not such as to render that fact conspicuous, else he might have been called upon for work which, in view of his consciousness (conscientiousness) and inherent modesty, could easily have seriously interfered with his scientific pursuits. He did, however, give his services as a trustee to the affairs of the Hopkins Grammar School of New Haven, and he acted for many years (17) as treasurer of its funds, which had come down in part from colonial times.

Gibbs was extremely painstaking in everything that he did and pronounced judgment only after mature consideration. In faculty meetings, he spoke seldom, but when he spoke, it was to the point. It is said that on one occasion, after a lengthy discussion as to the relative merits of the languages and mathematics, Gibbs said: "Mathematics is a language too." Gibbs was kindly in disposition, considerate and ready to be of help to his students. He had a sense of humor and smiled easily. He never sought for honors or advancement except as they came through recognition of his work. Such honors came to him in great abundance. They need not be enumerated here; I mention only the Copley Medal awarded him by the Royal Society of London, in 1901. He was made an honorary member of nearly every scientific organization of note and received honorary degrees from many of the leading universities of the world.

Outstanding qualities of Gibbs's character are his modesty and his devotion to science. He had not a few traits in common with Michael Faraday. At the beginning of the most productive period of his career, Faraday renounced all consulting work, from which he derived an income of from 500 to 1,000 pounds per annum—his salary at the Royal Institution was 100 pounds; for nine years following his appointment as professor of mathematical physics at Yale, Gibbs served without compensation. Gibbs, like Faraday, had great physical insight. Faraday, without mathematical training, invented the concept of the electromagnetic field, which later provided Maxwell with the foundation for the electromagnetic theory; Gibbs, with little experience with material systems, invented new physical concepts, that have served as a basis for the development of chemistry during the past fifty years.

Of the inner workings of Gibbs's mind, we know little; he left behind few letters and no notes. We can best judge the quality of the man by what he said of his colleague, Hubert Anson Newton, in the Biographical Memoir which he wrote for the National Academy of Sciences. Here, in speaking of his friend, he unconsciously reveals himself. After discussing Professor Newton's scientific contributions, Gibbs writes:

> But these papers show more than the type of mind of the author; they give no uncertain testimony concerning the character of the man. In all these papers we see a love of honest work, an aversion to shams, a caution in the enunciation of conclusions, a distrust of rash generalizations and speculations based on uncertain premises. He was never anxious to add one more guess on doubtful matters in the hope of hitting the truth, or what might pass as such for a time, but was always ready to take infinite pains in the most careful testing of every theory. With these qualities was united a modesty which forbade the pushing of his own claims and desired no reputation except the unsought tribute of competent judges.

These words of Gibbs characterize Gibbs himself much more truly than anything that I might hope to say.

OBITUARY

PROFESSOR S. P. L. SORENSEN

THE American students who were privileged to work with Professor Sørensen and the many who found inspiration in his scientific articles regret the death of this distinguished scientist on February 12.

Sørensen succeeded Kjeldahl as director of the chemical division of the Carlsberg Laboratory, in Copenhagen. Each of these men, in addition to many other contributions, hit upon something that has made his name a household word in chemical laboratories.

It would be trivial to say that Sørensen introduced the symbol p_H for a unit in a scale of acidity. The significance of the fact that this symbol has become almost as common as that for degree centigrade pertains to an aspect of science that too often is neglected. By means of his logarithmic scale Sørensen was able to place on one chart or one sort of chart several of the relations in acid-base systems that were known in principle but that had not vividly impressed potential users of the theory. In terms of his new exposition Sørensen evaluated those stable mixtures of acids and their salts that are called buffer mixtures and the zones of transformation of many indicators. Having systematized the indicator method of determining pH values Sørensen revealed something of its wide usefulness by resolving an old problem in enzyme chemistry, namely, the dependence of the activities of specific enzymes upon the degrees of acidity of the solutions. Here, then, in the classical paper "Études Enzymatiques," II (1909), supplemented by a more detailed mathematical analysis in 1912, was presented that rare combination of a vivid exposition of principles, exact quantitative data that

not merely illustrated the principles but also were immediately applicable as standards of reference and an illustration of the applications of a tool.

Largely because of this excellence of exposition, elaborated by Michaelis and others, there followed one of the most remarkable movements in the history of science. Every science having to do with water solutions soon instituted the measurement and control of "hydrogen-ion concentration" by the methods that Sørensen polished and in the terms that he introduced.

At a time when protein solutions were regarded as subject to study only by the unique methods of colloid chemistry Sørensen boldly applied the classical methods that work well in the study of the simple amino acids. Here, however, were problems requiring meticulous regard for detail, and because he had regard for what the problem demanded Sørensen's papers on protein solutions make difficult reading. In them will be found many of the bases of modern work, notably the application of Gibbs's phase rule in determining the homogeneity or heterogeneity of protein preparations, and the characterization of proteins by their isoelectric points and other indices of their properties as amphoteric electrolytes.

The meticulous exactitude that Sørensen displayed in his work on proteins is characteristic of his work as a whole—work that extended to analytical methods on the one hand and to organic synthesis on the other.

Born on a small farm near Slagelse on Sealand, Denmark, Sørensen developed early a penchant for science. He twice won the university's gold medal for outstanding work in science at the University of Copenhagen. After serving as assistant chemist in the Royal Technical College he became director of the chemical division of the Carlsberg Laboratory two years after receiving his doctor's degree in 1899. He became president of the Danish Academy of Sciences and last year was made a foreign associate of our National Academy of Sciences. He had honorary degrees from many universities.

In 1924 Professor Sørensen and his wife, with whom he had then and has since published several papers on proteins, visited America. We who had drawn inspiration from the written word were then impressed anew by this charming couple. Of a retiring disposition Professor Sørensen was every inch the gentleman who commanded respect by the quality of his thought and who won affection by the kindliness that shone in every glance and gesture.

WM. MANSFIELD CLARK
THE JOHNS HOPKINS UNIVERSITY
SCHOOL OF MEDICINE

FABIAN FRANKLIN

FABIAN FRANKLIN was born in Eger, Hungary, on January 18, 1853. He obtained his Ph.B. degree from Columbian University (now George Washington University) in 1869 and entered the department of mathematics of the newly established Johns Hopkins University in 1877. He remained at the university as fellow from 1877 to 1879, assistant from 1879 to 1882, associate from 1882 to 1889, associate professor from 1887 to 1892 and professor of mathematics from 1892 to 1895, at which time he resigned his position to enter professionally the field of journalism. He died on January 8, 1939.

Professor Franklin was a very unusual and inspiring teacher. After a lapse of almost half a century former students still remember how clear and satisfying his lectures were. He was never content to expound a theory as it was developed by its author, and his hearers had the distinct impression that the matter being presented had been thoroughly digested by the lecturer and carried the stamp of his individuality and artistic nature. He was most conscientious and painstaking with his students, frequently going to great pains to answer a question whose import the student barely realized. His simple demeanor and dignity of person commanded the instant respect of his students, a respect which was never lost.

In his mathematics itself were reflected the wide interests of his inquiring mind. This was a definite fault of his genius. To leave a mark in mathematics requires an *esprit de suite* which doggedly pursues to the bitter end some path into the unknown. The professional mathematician, on noting a characteristic flash of genius or originality in one of Franklin's short papers, may well wish that he had not been so versatile nor so interested in politics or world affairs; but such wishes are idle. In the short period of some fifteen years before he definitely abandoned mathematics for journalism, he published some thirty papers, most of which appeared in the *American Journal of Mathematics* or the Johns Hopkins University circulars. His earlier work on invariant theory shows clearly the influence of Sylvester, whilst his papers on circular coordinates and on bicircular curves demonstrate his geometrical insight. His elementary proof of a theorem on partitions has become classic.

In 1895, when Franklin was forty-two years old, he retired from his professorship of mathematics at the Johns Hopkins University to become editor of the Baltimore *News*. Later he became associate editor of *The New York Evening Post* and editor of the *Weekly Review*. He was a distinguished writer on economic, social and political subjects. His wife, Christine Ladd-Franklin, known for her work in psychology and logic, died in 1930.

F. D. MURNAGHAN
THE JOHNS HOPKINS UNIVERSITY

EARL E. HOOVER

EARL E. HOOVER, biologist of the New Hampshire State Department of Fish and Game, died at Con-

cord on January 8, after an acute illness of several weeks. Of all the younger workers he showed perhaps the greatest promise of leadership in the impending development of the science and art of freshwater fish management. Three annual survey reports, the last of which was only recently published, stand as tributes to his energy and competence. He made worth-while contributions to herpetology as well as ichthyology and fisheries science, and was engaged in a brilliant and pioneering research dealing with the effect of altered periods of daylight on the time of reproduction in fishes. An investigation of dwarfing in trout, from the systematic and evolutionary as well as fisheries view-point, was well under way and was to have been utilized for a doctorate dissertation at the University of Michigan.

Hoover was born at Somerset, Pennsylvania, on December 5, 1911. His undergraduate studies were carried on at Lebanon Valley College, and graduate work was done at the Johns Hopkins University, where he served as instructor in 1934–35. Before assuming the position in New Hampshire in 1936, he worked one year as field zoologist in the National Park Service. Despite a tragically short career, Earl Hoover made many friends and a very real impression in several fields of scientific endeavor.

CARL L. HUBBS

RECENT DEATHS

DR. WILLIAM EBENEZER FORD, since 1920 professor of mineralogy at Yale University, with which he had been connected since he graduated in 1899, died on March 23 at the age of sixty-one years.

DR. FRANK NELSON GUILD, professor emeritus, formerly head of the department of geology and mineralogy of the University of Arizona, died on March 12 at the age of sixty-eight years. Dr. Guild had been a member of the faculty of the University of Arizona since 1897.

THE death is announced of Dr. Gustav Hellmann, professor of meteorology at Berlin.

SCIENTIFIC EVENTS

EXCURSIONS AT THE CALIFORNIA MEETING OF THE AMERICAN GEOLOGICAL SOCIETY OF AMERICA

A SUMMER meeting of the Geological Society of America will be held under the auspices of the Cordilleran Section from August 8 to 10 at the University of California at Berkeley. In conjunction with the society there will be meetings of the Paleontological Society, the Seismological Society and the Society of Economic Geology.

An elaborate program of excursions has been arranged. These include three mutually exclusive local excursions to points of interest near San Francisco Bay scheduled for Thursday afternoon, August 10. One excursion will follow the course of the Haywards fault along the front of the Berkeley Hills. This fault is similar to the San Andreas fault in that the chief movement has been horizontal. Distinctive features of the fault will be visited. A second excursion will visit quarries where the Miocene bedded opaline cherts are exposed. A third excursion will visit Hunters Point in San Francisco. Here, Jurassic Franciscan rocks are well exposed.

More extended excursions have been planned to start on Friday, August 11. For these excursions, advance registration is necessary. If an insufficient number of reservations is made for a particular excursion, it will be cancelled. The cost of the proposed excursions can not be quoted at this time, but it is estimated that $5.00 to $6.00 per day should be ample for all expenses exclusive of transportation.

(1) An excursion to Yosemite Valley will illustrate the glacial phenomena of the Sierra Nevada, including the succession of the glacial periods. It is planned to conduct the excursion across the Sierra Nevada to Mono Lake, where the eroded fault scarp of the Sierras may be studied in its relationship to the glacial features.

(2) A second excursion for those interested in metalliferous deposits will include two of the mining districts in the Sierra Nevada and Virginia City.

(3) A third excursion has been planned to Lassen Peak, the source of the volcanic eruptions in 1914–1917.

(4) A series of one-day excursions has been arranged for those interested in paleontology and stratigraphy. With the exception of the excursion to San Francisco and Half Moon Bay, these are all within reach of Berkeley, so that participants in this group of excursions should reserve their rooms in Berkeley to Sunday, August 13. Friday, August 11, will be spent at San Pablo Bay, where Miocene invertebrate fossils can be collected. Saturday, August 12, will be spent collecting Eocene fossils near Martinez. Sunday, August 13, will be spent at the Museum of the California Academy of Sciences, in San Francisco, and participants will drive to Half Moon Bay in the late afternoon. Monday, August 14, will be spent at Half Moon Bay, studying recent organisms. In addition, some of the Tertiary rocks of the San Francisco peninsula will be examined.

(5) If a sufficient number of geologists are interested, an excursion will be arranged for Thursday, August 17, in Los Angeles. Some of the oil fields will be visited, and the Tertiary stratigraphy of the Los Angeles Basin will be examined.

All the excursions are open to fellows and guests;

but those wishing to participate in the post-session excursions are urged to apply not later than May 5.

AWARDS OF THE ALFRED P. SLOAN FOUNDATION

THE Alfred P. Sloan Foundation has made a grant of $25,000 to the Automotive Safety Foundation. With this gift fellowships will be established to give seven state highway engineers and twelve state policemen training at Yale University or Northwestern University for the academic year 1939–40. The awards provide for tuition, living and field expenses.

Twelve Sloan fellows at the Northwestern University Traffic Institute and seven at the Yale Bureau for Street Traffic Research now are completing their courses of study and this year will return to the official positions from which they received leaves of absence. The official announcement reads:

> The fellowship awards have been made available for the second year in the belief that the traffic problem will yield to the broad application of proved techniques and that progress in traffic control will be measurably accelerated when the services of adequate numbers of trained men are made available. Scientific methods and professionally trained personnel have contributed so much to the advancement of the economic value of motor transportation that commensurate relief for the traffic problem through these factors may be confidently anticipated.

The foundation had previously made a grant of $32,500 to the Massachusetts Institute of Technology for the award of fellowships to ten young industrial executives to take up special social and economic training there next June. The awards range from $1,750 for single men to $2,750 for those who are married.

The fellows, who will have a year's leave of absence from their present positions, have been selected on a competitive basis. They are between the ages of 25 and 35 and have had at least five years' industrial experience, part of it in an executive capacity. They are required to be graduates with high academic records in science or engineering of an accredited college or university. Emphasis is placed on managerial ability, seasoned intellectual capacity and a sensitivity to the social and civic implications of industry.

ELECTION OF FELLOWS OF THE ROYAL SOCIETY, LONDON

AT a meeting of the Royal Society held at Burlington House, London, on March 16, the following fellows were elected:

ADAIR, G. S., assistant director of research in physiology, Cambridge, distinguished for his researches on the physical chemistry of proteins, particularly in connection with haemoglobin.

ANDREWES, C. H., pathologist, National Institute for Medical Research, distinguished for his work on filtrable viruses and the bacteriophage, particularly in relation to the neutralization of viruses by antisera, and his studies on filtrable tumors.

BORN, M., Tait professor of natural philosophy, University of Edinburgh, distinguished for his work in many branches of mathematical physics and particularly for his contributions to quantum theory and its applications to physics and chemical physics.

BRADLEY, A. J., assistant director of research in crystallography, Cavendish Laboratory, Cambridge, distinguished for his methods of applying x-ray crystallography to elucidate the structure of metals and particularly the gamma phase and order and disorder in alloys.

BRUNT, D., professor of meteorology, Imperial College, London, distinguished for his contributions to analytical and dynamical meteorology, and particularly to the theory of the transfer of heat in the atmosphere.

CREW, F. A. E., Buchanan chair of animal genetics, University of Edinburgh, distinguished for his work on sex reversal in frogs and birds and on the genetics of many animals, especially Drosophila and budgerigars.

EDWARDS, F. W., department of entomology, British Museum, distinguished for his extensive researches on the order Diptera and for his studies on larval characters in relation to classification.

JONES, B. M., Mond professor of aeronautical engineering, Cambridge, distinguished for his researches in aeronautical science and for the elucidation of problems of design, such as the control at slow speeds and the determination of drag on full-scale structures.

KAYE, G. W. C., superintendent, department of physics, National Physical Laboratory, distinguished for his pioneer work in x-ray measurements and for his studies on acoustics and physical constants; has rendered valuable service to the Radium Protection Committee and the National Radium Commission.

LIDDELL, E. G. T., fellow of Trinity College, Oxford, distinguished for his researches upon the physiology of muscle movement and posture in mammals, and upon their control during the normal and abnormal functioning of central nervous mechanisms.

MASKELL, E. J., lecturer in plant physiology, Cambridge, distinguished for his work in the realm of plant physiology, especially in relation to problems of translocation.

MASSON, I., vice-chancellor of the University of Sheffield, formerly professor of chemistry, University of Durham, distinguished for his researches in physical chemistry, particularly on the physical interaction of mixed gases and on new aspects of the chemistry of iodine.

MEES, C. E. K., vice-president of the Eastman Kodak Company, Rochester, N. Y., distinguished for his influence on the technology of photography, thereby assisting advance in many branches of science.

NEWMAN, M. H. A., lecturer in mathematics, Cambridge, distinguished for his contributions to pure mathematics, particularly in the field of topology and group theory.

READ, H. H., professor of geology, Imperial College, London, distinguished for original work, especially in

connection with the tectonic and petrological problems of the igneous and metamorphic rocks of northern Scotland.

STAPLEDON, SIR R. G., professor of agricultural botany and director of the Welsh Plant Breeding Station, Aberystwyth, distinguished as the founder of the Welsh Plant Breeding Station where, with a team of workers, he has undertaken studies of far-reaching importance on the improvement of pastures.

TURNBULL, H. M., professor of morbid anatomy and director of the Bernhard Baron Institute of Pathology, London Hospital, distinguished for his work on morbid histology, particularly in relation to vascular disease, encephalitis, toxic hepatitis, diseases of bone, and normal and abnormal haemopoiesis.

TURNER, E. E., head of the department of organic chemistry, Bedford College, London, distinguished for his contributions to the stereochemistry of organic compounds, especially in connection with asymmetry in derivatives of diphenyl and with dissymmetry in the phenoxarsines.

WIGGLESWORTH, V. B., reader in medical entomology, London School of Hygiene and Tropical Medicine, distinguished for his researches on insect physiology, especially in relation to digestion, tracheal respiration, excretion and possible endocrine secretion.

WILLIAMS, E. J., professor of physics, University of Wales, Aberystwyth, distinguished for his researches on the passage of electric particles through matter, and on individual collision processes, which have provided evidence for the existence of the heavy electron.

THE ESTABLISHMENT OF AN INSTITUTE OF TECHNOLOGY AT NORTHWESTERN UNIVERSITY

THE trustees of Northwestern University have approved the establishment of an Institute of Technology which is to be conducted on the cooperative basis under which students will spend alternate periods, in school and in industries. This plan was originated by Professor Herman Schneider,[1] of the University of Cincinnati, and has now been adopted in a number of schools.

The institute has been made possible by the offer of the Walter P. Murphy Foundation, an Illinois corporation founded by Walter Patten Murphy, a Chicago manufacturer of railway equipment, to build and equip the unit, the total cost of which will be approximately $6,500,000. It will provide for about eight hundred students in the departments of civil, mechanical, electrical and chemical engineering.

Work on the physical plant will commence immediately. It will house the institute as well as the present departments of physics and chemistry of the university. The new unit will be built at Evanston on the land immediately to the south of the present men's quadrangles. It will have a frontage of approximately five hundred feet along Sheridan Road.

[1] Dr. Schneider died on March 28.

The school will adopt the cooperative plan of engineering education now in operation at several leading engineering schools. It will be conducted in conjunction with the other schools and departments of the university, and will share their present social, academic and research facilities.

It will embrace a research laboratory and, at the outset, four main divisions: civil, mechanical, electrical and chemical. Provision has been made, however, for adding more divisions, particularly those of applied arts, economics, metallurgy and aeronautics. Other departments and bureaus of research will be set up from time to time as deemed advisable to meet educational and engineering needs.

A careful check-system of selecting freshmen will be adopted at the outset, to provide a student body of exceptional intelligence and capabilities. Although entrance requirements will be high, other factors such as aptitude for work, character, resourcefulness, personality, will also bulk large in the selective process.

The courses will be designed so that each student will be provided with the necessary elements of a true liberal education. Training in the arts and social sciences, as well as in mathematics and the basic physical sciences, will be rigorously required.

The students' advisers will have ample time for frequent interviews with each student, to study his development and to help him to solve his problems. Each student will have careful supervision while he is working in industry. Care will be taken not to place too many students in a single firm, in order that they may receive more adequate individual supervision.

Students will be afforded ample opportunities to engage in social, athletic and intellectual activities outside the classroom. They will live in dormitories occupied by students from other schools during the period of work in industry as well as during that spent on the campus.

The progress and expansion of the new school will be subject to close scrutiny, and changes in curriculum and organization will be made slowly as time and differing conditions require.

Dr. Walter Dill Scott, president of the university, has made the following statement:

Northwestern University and its trustees are exceedingly grateful for this munificent gift and the trust that has been placed with this institution.

The foundation's decision to establish this institute of technology at Northwestern is motivated by a desire to make the greatest possible contribution to the social, industrial and educational advancement of this nation. They have made this decision after a long, exhaustive survey by a corps of men who personally investigated institutions and educational plans from coast to coast before recommending the establishment of the new institute at Northwestern.

The school's purpose will be to produce men of social vision and sound training, who have a definite understanding of the problems awaiting them in industry and society. This program will be accomplished through joint action with the industries of Chicago and the Midwest in the cooperative plan of education.

I am convinced that this plan—whereby the student works concurrently in industry and in the university—is ideally suited to train engineers. However, though we shall begin work immediately, so that the new school will be ready by next year, the program will be developed gradually, and will always be flexible enough to meet changing conditions.

Not only as president of Northwestern University, but as a citizen of Chicago and Evanston, I rejoice at this great forward step, which I am enabled to announce during my last year as president. I am sure that it will have a profound influence on education and industry in America.

This new school is significant for Chicago because it will enable us to create here one of the world's great centers for engineering education and research. It is significant for industry because it will develop men who, through careful selection and rigid training, offer greatest promise of making contributions to industry and the engineering profession. It is significant for the engineering student because it is designed to furnish a training that will develop him to his maximum possibilities.

That we are exceedingly grateful to the Walter P. Murphy Foundation for having selected Northwestern University as the agent for carrying out this great educational program goes without saying. We pledge the cooperation of every department of the university toward making the new school a great center for engineering training and research.

SCIENTIFIC NOTES AND NEWS

ATTENTION has already been called in SCIENCE to the program of the spring meeting of the American Chemical Society, which will be held in Baltimore from April 3 to 7. Professor Charles A. Kraus, of Brown University, will preside. Dr. J. C. W. Frazer, Baker professor of chemistry at the Johns Hopkins University, is honorary chairman of the meeting, and Dr. John C. Krantz, Jr., professor of pharmacology in the Medical School of the University of Maryland, is general chairman. A general meeting will be held on the afternoon of April 3, at which addresses will be given by Dr. Vincent du Vigneaud, of Cornell University Medical College, on "Isotopes as a Tool in the Study of Intermediary Metabolism" and by Dr. Harold R. Moulton, president of the Brookings Institution, on "The Chemical Industry and the Economic System."

THE Franklin Medal of the Franklin Institute of the State of Pennsylvania has been awarded to Dr. Edwin Powell Hubble, of Mount Wilson Observatory, Pasadena, Calif., and posthumously to Dr. Albert Sauveur, late emeritus professor of metallurgy and metallography of Harvard University. The medal is awarded to Dr. Hubble "in recognition of his extensive study of the nebulae, particularly those outside our galaxy, as a result of which the dimensions of observed space have been greatly increased." The award to the late Dr. Albert Sauveur is made "in recognition of his outstanding work in the science of metallography, and of his many contributions to this branch of metallurgy which have been in a large measure responsible for changing the heat treatment of steel from an art to a science."

THE Western New York Section of the American Chemical Society has announced the award of the Jacob F. Schoellkopf Medal for 1939 to Charles F. Vaughn, of the Mathieson Alkali Works, in recognition of his work "in the graphitization of carbon, his successful development and operation of the Castner mercury cell where all others failed, and his unqualified ability as an executive and administrator, placing him in the front rank of those who have made lasting contributions to the chemical industry."

A DINNER was held on March 28 in honor of Dr. Carl Beck, formerly professor of surgery at the Chicago College of Physicians and Surgeons, now the College of Medicine of the University of Illinois, in recognition of his seventy-fifth birthday and the completion of fifty years in the practice of medicine.

THE twenty-fifth anniversary of Director Frederick M. Gaige as a member of the staff of the Museum of Zoology of the University of Michigan was commemorated by the establishment of the Frederick M. Gaige Research Fund, recently accepted by the regents. The income from this gift, to which more than fifty separate donors have contributed the sum of $1,558, will be used for the promotion or publication of research carried out in the museum.

THE Hallett prize of the Royal College of Surgeons, London, was presented on March 9 to Dr. Alfred McKee Large, of Toronto.

THE Academy of Sciences at Halle has awarded the Carus Medal to Dr. Otto Grosser, professor of anatomy at the German University of Prague. The Forel prize and plaque have been awarded to Dr. Ernst Gabriel, of the University of Vienna.

THE University of Liverpool will confer in May the doctorate of science on Dr. Martin Knudsen, professor of physics in the University of Copenhagen and chief

adviser in physical oceanography to the International Council for the Exploration of the Sea.

MILLS COLLEGE conferred on March 16 the doctorate of humane letters on Eve Curie, who is visiting the United States.

THE honorary degree of doctor of science will be conferred by the University of Cambridge on Dr. W. N. Haworth, Mason professor of chemistry at the University of Birmingham, and on Sir Henry Dale, director of the British National Institute for Medical Research.

PROFESSOR F. G. DONNAN, emeritus professor of chemistry of the University of London, has been elected an honorary member of the Société Philomathique of Paris.

IT is announced in *Nature* that honorary members of the Royal Meteorological Society have been elected as follows: Jules Jaumotte, director of the Royal Meteorological Institute of Belgium; Dr. Carl-Gustaf Rossby, professor of meteorology at the Massachusetts Institute of Technology, and Philippe Wehrlé, director of the National Meteorological Office of France.

OFFICERS of the Physical Society, London, have been elected as follows: *President,* Professor Allan Ferguson; *Vice-presidents,* Professor G. I. Finch, Dr. Ezer Griffiths, Dr. L. Hartshorn and R. W. Paul; *Honorary secretaries,* J. H. Awbery and Dr. W. Jevons; *Honorary foreign secretary,* Professor O. W. Richardson; *Honorary treasurer,* Dr. C. C. Paterson; *Honorary librarian,* Dr. J. H. Brinkworth.

DR. ROYAL N. CHAPMAN, at present director of the experiment station of the Pineapple Producers Cooperative Association, of Honolulu, has been appointed dean of the Graduate School of the University of Minnesota. Dr. Chapman was formerly a member of the faculty at University Farm, where he served as head of the division of entomology and economic zoology, resigning in 1930 to go to Hawaii when the pineapple plantations were threatened with serious insect damage. He succeeds Dr. Guy Stanton Ford, who was dean of the school from 1913 until he was elected president of the university last autumn. During the past two years Dr. W. S. Miller, professor of educational psychology, has been acting graduate dean. Dr. Gerald T. Evans, now assistant professor of biochemistry at Yale University, has been appointed director of the chemical-metabolic laboratories in the Medical School and the University Hospital, with the rank of associate professor of medicine.

DR. MAXWELL EDWARD LAPHAM has been elected dean of the School of Medicine of Tulane University. The present dean, Dr. Charles C. Bass, Irby professor of experimental medicine, who began his professional connection with the university in 1904, will reach the retiring age early in 1940, and the work of his office will be taken over by Dr. Lapham at that time.

DR. JULIUS M. ROGOFF, recently visiting professor of physiology at the University of Chicago and formerly associate professor of experimental medicine at Western Reserve University, has been appointed professor of endocrinology of the School of Medicine of the University of Pittsburgh. A special laboratory has been established and designated as the laboratory of experimental endocrinology, where he will conduct experimental work in this field. The laboratory is supported by the G. N. Stewart Memorial Fund.

PROFESSOR FRANK CLIFFORD STOCKWELL, Anson Wood Burchard professor of electrical engineering and head of the department of electrical engineering at the Stevens Institute of Technology, has been appointed dean of the Graduate School, under the new plan of organization of graduate studies which was recently approved by the trustees.

DR. CARL R. MCCROSKY has been named chairman of the department of chemistry at Syracuse University, with which he has been associated for twenty years. He succeeds Reginald S. Boehner, who resigned recently because of ill health and who will be on leave of absence for the rest of the year. Dr. Boehner will retain the professorship of organic chemistry.

DR. WAGNER SCHLESINGER, son of Dr. Frank Schlesinger, director of the Observatory of Yale University, has been appointed director of the Fels Planetarium of the Franklin Institute, Philadelphia. He succeeds Dr. James Stokley, who has been made head of the newly established Buhl Planetarium and Institute of Popular Science in Pittsburgh.

DR. JOHN S. HALL, of Amherst College Observatory, has been awarded a premium of $500 for his investigations on the velocity of light. This is a portion of the fund established by Uriah A. Boyden, of Boston, in 1859, "to be awarded to any resident of North America who shall determine whether all rays of light and other physical rays are or are not transmitted at the same velocity."

THE J. T. Baker Chemical Company research fellowship in analytical chemistry for the Eastern Division has been awarded to Frank K. Pittman, of the Massachusetts Institute of Technology.

PROFESSOR OTTO SCHMIDT, the Polar explorer and head of the Soviet Northern Sea Route Administration, has resigned his position to take up work as vice-president of the Academy of Sciences. He is suc-

ceeded on the Northern Sea Route Administration by Ivan Papanin, who was a member of the party that spent the winter of 1937–38 on an ice-floe.

THE LONDON *Times* states that the Secretary of State for Air, Sir Kingsley Wood, on the recommendation of the director of Medical Services, Royal Air Force, has appointed the following standing committee to investigate and advise him on the medical aspects of all matters concerning personnel which might affect safety and efficiency in flying: Professor Sir Edward Mellanby, *chairman,* Professor F. C. Bartlett, E. A. Carmichael, C. S. Hallpike, Dr. B. H. C. Matthews, Sir John Parsons, Professor L. J. Witts. The representatives of the Air Ministry on the committee will be Air Vice-Marshal A. V. J. Richardson, director of Medical Services, and Air Commodore H. E. Whittingham.

DR. GEORGE HOYT WHIPPLE, dean and professor of pathology at the School of Medicine and Dentistry of the University of Rochester, will give the Adam M. Miller lecture at the Long Island College of Medicine on April 6. His subject will be "Experimental Anemia and the Building of Hemoglobin in the Body."

UNDER the title "The World's Least Known Tropical Seacoast," Dr. Robert Cushman Murphy, of the American Museum of Natural History, lectured on March 21 before the members of the American Geographical Society on his recent field work along the Pacific coast of Colombia.

DR. LAWRENCE KOLB, assistant surgeon general of the U. S. Public Health Service in charge of mental hygiene, gave on March 1 a lecture on "Drug Addictions" at the School of Medicine of Duke University. On March 8 a motion picture film on industrial accidents and their care was shown by Dr. Henry H. Kessler, specialist in cineplastic surgery.

DR. CHARLES ATWOOD KOFOID, emeritus professor of zoology at the University of California, and Dr. F. W. Went, professor of plant physiology at the California Institute of Technology, were the principal speakers at a biology colloquium held on March 4 at the Oregon State College. The colloquium, which attracted some three hundred scientific men from Oregon and neighboring states, was sponsored by the Oregon State College Chapter of Phi Kappa Phi, the scholastic honor society.

THE School of Medicine of Western Reserve University opened a series of fourteen lectures on "The Social and Economic Aspects of Medicine" on March 17. They will be continued twice weekly until May 9. Besides a number of Cleveland authorities, the speakers will include Dr. Morris Fishbein, editor of the *Journal* of the American Medical Association; Dr. Ralph C. Williams, senior surgeon, U. S. Public Health Service; Dr. Sidney McCurdy, medical supervisor, the Ohio Industrial Commission; Dr. C.-E. A. Winslow, Lauder professor of public health at the School of Medicine of Yale University. The series will be divided into three parts as follows: "A Dynamic Society Encounters Medical Problems," "The Medical Billion and Where It Goes" and "Democracy Feels Its Way."

THE Gehrmann lectures for 1938–1939 of the College of Medicine of the University of Illinois will be delivered in the Medical and Dental College Laboratories building on April 12, 13 and 14 by Dr. Herbert C. Clark, director of the Gorgas Memorial Institute of Tropical and Preventive Medicine of the Panama Canal Zone. The titles of the lectures follow: "Malaria, its Effect on Labor Efficiency in the Tropics"; "Amoebiasis, Clinical and Non-Clinical"; "Modern Factors Favoring Spread of Diseases."

THE Franklin Institute of the State of Pennsylvania will hold an assembly and dinner at the institute on March 31 in honor of the Carbide and Carbon Chemicals Corporation, E. I. du Pont de Nemours and Company, Libbey-Owens-Ford Glass Company, Monsanto Chemical Company and Pittsburgh Plate Glass Company, "for their progressive attitude in carrying on the Benjamin Franklin ideal of the application of science to industry for the benefit of mankind."

THE annual meeting of the French Association for the Advancement of Science will be held at Liège from July 17 to 22, under the presidency of Professor Charles Fabry, director of the Optical Institute, Paris.

ARRANGEMENTS have been made for a joint meeting of the American Meteorological Society and the Royal Meteorological Society of Great Britain at Toronto on August 28 and 29, at which a number of the delegates to the seventh assembly of the International Union of Geodesy and Geophysics will be present. The program will comprise two symposia, one on radiation and the other on extra-tropical cyclones. The meeting will immediately precede a trip which has been arranged by the Travel Committee of the International Union scheduled to leave Kingston, Ontario, on the morning of August 30. Further information will be contained in the forthcoming circular to delegates and guests to be issued early in April.

FOR the Milwaukee meeting the Section on Zoological Sciences (F) of the American Association for the Advancement of Science is planning to hold sessions on June 20, 21 and 22. The sessions on Tuesday will be devoted to an invitation program on "Regeneration," under the chairmanship of Professor J. W. Buchanan, of Northwestern University. On Wednesday another invitation program on genetics will be held under the chairmanship of Professor L. J. Cole, of the University of Wisconsin. The Thursday session will be de-

voted to a general program of contributed papers. Titles for this session should be sent by April 15 to Dr. George A. Baitsell, secretary of the section, Yale University, New Haven, Connecticut.

SIGMA PI SIGMA, the national physics honor society, will hold its convention on April 6, 7 and 8 at Columbus, Ohio, with the Ohio State University Chapter as host. Delegates from over thirty active chapters will attend the business and scientific sessions, which will conclude with an inspection trip to the Perkins Observatory. Dr. R. C. Colwell, of West Virginia University, the retiring president, will deliver the presidential address on "Electromagnetic Waves and Radio Signals." After being received into honorary membership in the society, Dr. Paul E. Klopsteg, of the Central Scientific Company, will speak at an open meeting on "Archery, a Physicist's Hobby." At a panel discussion, Dr. M. N. States, assisted by Dr. W. P. Davey, Dr. W. E. Forsythe and others, will present various phases of problems dealing with the placement of graduates in physics.

THE Emmons memorial fellowship in economic geology of Columbia University is available for this year with a stipend of $1,200. Applications and accompanying testimonials should be submitted not later than April 15. Applicants should be qualified by training and experience to investigate some problem in economic geology and should submit a definite statement of their problem to the committee, under whose oversight the work will be undertaken at any institution approved by them. The fellow must give his entire time to the problem, which may be used for a doctorate dissertation. Application blanks and further information may be obtained from Alan M. Bateman, Charles P. Berkey, Waldemar Lindgren, or the Secretary, Columbia University, New York, N. Y.

FOUR fellowships have been established at Yenching University by the British Boxer Indemnity Fund for the current academic year. The appointees will serve as research assistants in carrying forward definite research projects. These fellowships are primarily for graduates of Yenching University and carry a stipend of $480 per year. For the current year one appointment has been made in biology, one in physics and two in chemistry.

DR. VLADIMIR NIKOLAEVICH IPATIEFF, since 1930 professor of chemistry at Northwestern University, previously of Moscow and Leningrad, has made a gift of $21,000 to the university for the endowment of a chemical research laboratory for work in high pressures. The new laboratory will be placed in University Hall and will be used for research in chemical synthesis at high pressure. Dr. Ipatieff will be the director of the laboratory.

FORMER GOVERNOR PERCIVAL P. BAXTER has given to the State of Maine 12,000 acres of wild forest land in the Mount Katahdin region to be added to the Baxter State Park. The legislature in 1933 accepted Governor Baxter's first gift of 6,000 acres, which was subsequently named the Baxter State Park.

DISCUSSION

CLIMATE AND REPRODUCTION

WHITAKER'S recent discussion in these columns of the question of seasonal sterility among the Eskimos[1] may be regarded as yet another nail in the coffin of the myth of the human breeding season. The myth is one that dies hard. Westermarck in a discussion of the subject cited some two hundred references in support of the theory that the ancestors of modern man were characterized by a circumscribed pairing or breeding season.[2] The notion that the periods at which the greatest number of births occur among the human species indicate the survival of a primitive human sexual rhythm associated with "annual changes in the human organism especially connected with the sex function" was discussed very fully by Havelock Ellis many years ago.[3] These ideas find a place in the works of such distinguished physiologists as Marshall[4] and Wright,[5] and they have found a vigorous supporter in a leading student of population.[6]

Such authors have assumed that, since the catarrhine monkeys and the anthropoids are characterized by a pairing season, the ancestors of modern man must likewise have been so characterized and that certain primitive peoples still exhibit evidences of this "ancestral trait." It so happens that the major premise of this syllogism is a pure assumption without the slightest factual foundation, for the evidence is quite clear and definite that neither the catarrhine monkeys nor the anthropoid apes are characterized by a breeding season, but on the other hand that they are capable of breeding and of copulating at all times.[7] The state-

[1] W. L. Whitaker, SCIENCE, 88: 214, 1938.

[2] E. Westermarck, "The History of Human Marriage," Vol. II, p. 76, 1922; "The Future of Human Marriage," p. 10, 1936.

[3] H. Ellis, "Studies in the Psychology of Sex," Vol. II, p. 88, 1900.

[4] F. H. A. Marshall, "The Physiology of Reproduction," p. 672, 1910.

[5] S. Wright, "Applied Physiology," p. 198, 1934.

[6] A. M. Carr-Saunders, "The Population Problem," p. 92, 1922.

[7] For a discussion of the evidence which it is impossible

ments of travelers and of other occasional observers concerning the existence of an alleged breeding or rutting season among certain primitive peoples could be quoted *ad nauseam*, but there is one that has been so often quoted by those who have put their faith in a human breeding season, and which is so typical of all such statements, that it deserves to be given here together with the sort of evidence which puts such statements in the category to which they properly belong. Westermarck[8] begins his citation of the evidence in support of the existence of a breeding season in primeval man with the statement that "According to Mr. Johnston, the wild Indians of California, belonging to the lowest races on earth, have their rutting seasons as regularly as have the deer, the elk, the antelope, or any other animals.[9] With reference to some of these Indians, Mr. Powers says that spring 'is a literal Saint Valentine's Day with them, as with the natural birds and beasts of the forest.' "[10] When we consult our greatest authority on the California Indians for some light on these matters we find him writing of the Yurok, a Californian people who live along the reaches of the lower Klamath River, that they are characterized by an excessive desire for wealth and the great regard in which they hold money, which circulates among them in the form of dentalium shells.

> The significant fact is that they hold a strong conviction that the dentalium money and the congress of the sexes stand in a relation of inherent antithesis. This is one reason given for the summer mating season: the shells would leave the house in which conjugal desires were satisfied, and it is too cold and rainy to sleep outdoors in winter. . . . Births occurred among the Yurok and their neighbors chiefly in spring. This was, of course, not because of any animal-like impulse to rut in a certain season, as has sometimes been imagined, but because of highly specialized ideas of property and magic. . . . Since dentalia and other valuables were kept in the house, a man never slept there with his wife. . . . The institution of the sweat house rendered this easily possible. In summer, however, when the cold rains were over, the couple made their bed outdoors; with the result that it seems natural to the Yurok that children should be born in spring.[11]

Thus, when the superficial observations of the older observers are interpreted in the light of the facts they are seen to have a meaning quite different from that which has rather loosely been attributed to them.

In recent years, as a result chiefly of Rowan's work[12] on artificial illumination and sexual periodicity,[13] an attempt has been made to bolster up the breeding season myth in the special case of the Eskimo.[14] Whitaker has shown the unsatisfactory nature of the evidence upon which this attempt was based. In passing it may be remarked here that Rowan's work has been very generally misunderstood as proving that light *qua* light is the causative factor in producing gonadal development, whereas what Rowan has actually claimed to have shown is that it is more probably the effect of light, namely, *wakefulness*, which produces the observed effect.[15]

Now, while it is certain that no human beings are characterized by a circumscribed period of reproduction, there exists a certain amount of evidence which very strongly suggests that climatic factors do affect the reproductive capacity of most vertebrates, including man. Thus, for example, the breeding seasons of various birds and mammals can be shown to be correlated with certain seasons, and when these animals are removed from the Northern to the Southern Hemisphere, or *vice versa*, they adapt themselves after a short time to the reversed calendric seasons and come into oestrus in the season in which they formerly did, although in different months. This has been shown in the case of birds,[16] and for the mammals thus far investigated.[17] For the distribution in the incidence of conceptions in the primates with a high relative sterility and menstrual disturbance in the summer months this seasonal correlation has been shown to hold good in the case of the rhesus monkey,[18] and also for man.[19] The high frequency of disturbances of the menstrual cycle during the summer months in young and adult women has been reported by many investigators,[20] and it is also of some interest to note that

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to cite here see M. F. Ashley-Montagu, "Coming into Being Among the Australian Aborigines," p. 258, 1937.

[8] *Loc. cit.*, p. 81.

[9] A. Johnston, "The California Indians," in H. R. Schoolcraft, "Historical and Statistical Information respecting the History, Condition, and Prospects of the Indian Tribes of the United States," Vol. IV, p. 224, 1860.

[10] S. Powers, "Tribes of California," in "Survey of the Rocky Mountain Region," p. 206, 1877.

[11] A. L. Kroeber, "Handbook of the Indians of California," *Bureau of American Ethnology Bulletin*, Vol. 78, 41, 1925.

[12] W. Rowan, *Nature*, 115: 494, 1925; *Nature*, 120: 11, 1928; *Proc. Bost. Soc. Nat. History*, 38: 147, 1926; *Proc. Bost. Soc. Nat. History*, 39: 151, 1929.

[13] For a review of the literature dealing with this subject see T. H. Bissonnette, *Quart. Rev. Biol.*, 11: 371, 1936, and Rowan's forthcoming paper, "Light and Reproduction," *Biol. Rev.*, 13: 374, 1938.

[14] Ll. J. Llewellyn, *Nature*, 129: 868, 1932.

[15] W. Rowan, *Proc. Zool. Soc. London*, Ser. A, 108, Pt. 1: 51, 1938.

[16] J. R. Baker and R. M. Ranson, *Proc. Zool. Soc. London*, Ser. A. 108, Pt. 1, 101, 1938.

[17] F. H. A. Marshall, *Proc. Roy. Soc.*, 122 B: 413, 1937.

[18] C. G. Hartman, *Contrib. Embryol.* No. 134: 39, 1932.

[19] C. A. Mills and F. A. Senior, *Arch. Int. Med.*, 46: 921, 1930.

[20] E. T. Engle and M. C. Shelesnyak, *Human Biol.*, 6: 431, 1934; E. Allen, *Am. Jour. Obst. and Gynec.*, 25: 705, 1933; C. F. Fluhman, *Am. Jour. Obst. and Gynec.*, 26: 642, 1933; J. L. King, *Am. Jour. Obst. and Gynec.*, 25: 583, 1933.

the greatest number of abortions appears to occur during the summer months.[21]

Apart from the evidence provided by the lower vertebrates, the fact that the lowest number of conceptions, the greatest number of menstrual irregularities and the greatest number of abortions occur in the human species wherever investigated during the summer months indicates that the reproductive life of man is in some way influenced by climatic factors. That these factors are probably fairly complex should, for methodological purposes at least, be assumed, for it now seems unlikely that any one single factor such as light or temperature alone can be considered as the sufficient cause of these reproductive phenomena. The low summer conception rates among the Eskimo of Greenland as given by Bertelsen[22] and referred to by Whitaker is yet another illustration of this apparently universal relation between low reproductivity and the summer months. What the nature of this relation is here, as elsewhere, is a problem which remains to be investigated. The purpose of the present communication is to make it clear that such a relation exists.

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VITAMIN B_1 IN SOIL[1]

WILLIAMS and Spies[2] have advanced the theory that thiamin (vitamin B_1) may be present in soils. Since certain thiamin-requiring fungi are able to detect minute quantities of this substance (0.05 micrograms per liter), the writers undertook to test this theory. Duplicate soil samples were obtained from two different localities in the vicinity of Morgantown, W. Va. The first was taken from a cultivated field, and the second from a sharply sloping and sparsely wooded tract that has never been under cultivation. The soil sampler was driven to a depth of 4 feet and cores of soil one inch in diameter and 48 inches long were secured. The cores were divided into 4 one-foot lengths and separately extracted with pyridine water (3:1) for 5 hours on a steam bath. The extract was filtered off, taken to dryness under reduced pressure, repeatedly dissolved in water and dried until all traces of pyridine disappeared, and the pyridine-free extract was added to the basic medium containing the essential mineral salts, amino acids and dextrose. One half of the extract from each sample of soil was added to 50 ml of the nutrient medium, solidified with 2 per cent. purified Bacto agar, poured in test-tubes, sterilized and inoculated with the test organisms. The other half of the extract was tested without the addition of agar. The following organisms were used: (a), *Phytophthora erythroseptica,* a fungus that requires thiamin for its growth; (b), *Phycomyces blakesleeanus,* capable of growing in the presence of either thiamin or a mixture of the two moieties of thiamin—thiazole and pyrimidine; (c), *Pythiomorpha gonapodioides,* which grows equally well in the presence of either thiamin or pyrimidine only; (d), *Mucor ramannianus,* capable of making equally good growth in the presence of thiamin or thiazole alone, and (e), *Sordaria fimicola,* which does not grow in the presence of thiamin or its moieties alone, but must have one of the bioses—biotin. The control medium failed to induce growth in any of the foregoing organisms, while all five fungi flourished in both solid and liquid media containing soil extract. The extract from the surface foot of soil induced a better growth than that from the lower ones, but even the fourth foot of soil contained enough thiamin to induce fair to good growth.

Cores of soils taken at a depth of 8 feet from a pasture land showed that the soil contained enough pyrimidine seven feet under the surface, where the microflora is very sparse, to induce a rich growth in pyrimidine-requiring organisms; enough thiazole to induce a fairly good growth in *Mucor ramannianus,* and sufficient thiamin to promote some growth in *Phytophthora erythroseptica.* This shows that not all the thiamin or its moieties found in the soil remain associated with living organisms but that some may leach into the clay and remain adsorbed on the particles.

Robbins[3] and White[4] have shown that thiamin is essential for the cultivation of excised roots of tomato, while Bonner[5] has found that in certain plants root formation is induced only when thiamin is added to the rooting medium. Biotin is essential for numerous microorganisms, and since it is present in many plant and animal tissues, eventually it may be found to be of considerable importance in the biological processes. It may be possible that the presence of thiamin and biotin in soils will give added significance to the role of organic matter in soil fertility.

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PRESERVING THE VIABILITY OF BERMUDA ONION SEED

IT is well known that many seeds retain their viabil-

21 W. Millar, *Human Biol.,* 6: 279, 1934.

22 A. Bertelsen, *Meddelelser om Grønland,* 117: No. 1, 1935.

1 Published with the approval of the director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 216.

2 Williams and Spies, "Vitamin B_1," p. 381. Macmillan Company, New York, 1938.

3 Robbins and Bartley, SCIENCE, 85: 246–247, 1937.

4 White, *Plant Physiol.,* 12: 803–811, 1937.

5 Bonner, paper read at Richmond meeting of A.A.A.S., 1938.

ity for a comparatively short time, especially in a moist warm climate. Bermuda onion seed, which is used largely in our southern states, often gives trouble from low germination, even when the seed is not more than a year old.

Samples from a number of lots of Bermuda onion seed imported from the Canary Islands were combined and dried at a low temperature in a partial vacuum to 6.4 per cent. moisture content in November, 1924. Portions of this seed were stored (*a*) in paper packets at room temperature in the laboratory, and (*b*) sealed in air-tight containers and stored part at room temperature in the laboratory and part in a cool chamber at a temperature ranging from 5° C. to 10° C.

The seed has been tested from time to time, with the results given in Table 1.

TABLE 1
GERMINATION OF BERMUDA ONION SEED AFTER STORAGE

Length of storage	Germination after storage in		
	Paper packet in room, per cent.	Sealed tube in room, per cent.	Sealed tube in cold chamber, per cent.
Check test	94	94	94
16 months	83	88	89
3 years	36	94	93
7 years	0	89	91
11 years	..	89	87
13 years	..	90	89

This small experiment illustrates strikingly the importance of maintaining a low moisture content in stored seeds if vitality is to be preserved.

In plant breeding work, it is important to maintain original stocks of seed over long periods for purposes of comparison. This is especially important in the case of annuals and biennials. It is entirely feasible to artificially dry small lots of seed and store them in air-tight containers to preserve their viability for relatively long periods. A like procedure is practical for the storage of commercial seeds of valuable strains.

EDGAR BROWN

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U. S. DEPARTMENT OF AGRICULTURE

BACTERIA OF THE LISTERELLA GROUP ISOLATED FROM FOXES

THE recent report of Graham and his associates[1] on Listerellosis of cattle and sheep in Illinois has redirected our attention to an organism isolated in early June, 1937, from silver foxes from a nearby fur farm. The disease, which spread rapidly through the sheds, killing a considerable number of the young animals, was pronounced distemper by a prominent authority on fox diseases called into consultation by the attending veterinarian.

We did not learn much about the symptoms except that the animals became prostrate and were dead a few hours later. Examination of the internal organs revealed no significant changes. Heart's blood cultures from eight of the animals were made to beef heart infusion broth, and from five of them the cultures were positive. One of the positive cultures was from a very sick fox pup which was killed and the culture made immediately afterward. The organism, which was the same in all the cultures, is a slender gram positive even-staining rod in broth culture. Films made from blood agar slants show a gram positive rod similar in size, shape and arrangement to *Corynebacterium hoffmanni*. It is sluggishly motile. Doses of 0.5 cc of a 24-hour broth culture injected into each of two 400-gram guinea pigs proved fatal in two days with recovery of the organism from the heart's blood. Mice also proved susceptible.

The organism was considered to belong probably to the Listerella group. Dr. Graham has very kindly examined the culture and tentatively identified it as a "Listerella or Listerella-like type."

We have no evidence of etiological connection of this organism with this outbreak of disease among the foxes. We feel, however, that it must have had some significance, either as a primary or a secondary factor in the illness of those animals from which it was isolated.

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THE ANTI-MENORRHAGIC FACTOR OF MAMMALIAN LIVER FAT

FOLLOWING the introduction of oral liver extracts for the treatment of anemia it was observed by some physicians that some of these preparations were useful in controlling some cases of functional uterine bleeding (menstrual bleeding of prolonged or profuse nature, not due to benign or malignant tumors). Although the original purpose of the liver therapy was to treat the secondary anemia following this bleeding, there was often noted a diminution or cessation of the abnormal hemorrhage itself, even though the blood count was unaffected. This property was found in the cruder preparations but not in the highly purified oral or parenteral solutions. Since this purification involves no treatment likely to inactivate any constituent, the fraction in question was probably removed in the process. Inactive proteins and lipoids constitute much of the material removed in the purification of parenteral solutions.

Since 1936 we have been investigating the lipoid

[1] SCIENCE, August 19, 1938, page 171.

fraction of mammalian liver. Saponification of beef or hog liver fat in hot alcoholic potash for one hour yielded an orange-colored, non-saponifiable residue, which was tested on patients suffering from functional uterine bleeding. The administration by mouth of an adequate dosage completely controls the menorrhagia or metrorrhagia. Thus far our clinical observations indicate that in young women there is a cumulative effect lasting for months after its administration has been discontinued. Patients in the latter part of menopause who suffer from menorrhagia or metrorrhagia require much larger doses than the former group and show no cumulative effect, requiring treatment with each period. This apparent inverse dosage with the ovarian function suggests that its action is related to the functional activities of the gonads. Curtis[1] also has reported favorable results from the use of liver extract and of our fraction.

While it was known from the work of Dam[2] that liver fat contains the anti-hemorrhagic vitamin K, we did not consider the anti-menorrhagic factor to be related, since it withstands hot saponification. The recently reported observations of Lichtman and Chambers[3] indicate that there is a saponification-stable substance in liver fat which has some of the properties of vitamin K.

We are continuing the fractionation and testing of the anti-menorrhagic factor (produced commercially as "Anti-menorrhagic Factor"—Armour) and have begun experiments to determine the identity or non-identity of the anti-hemorrhagic and anti-menorrhagic factors.

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SCIENTIFIC BOOKS

RECENT BOTANICAL BOOKS

Economic Botany: A Textbook of Useful Plants and Plant Products. By ALBERT F. HILL. vii + 592 pp. 225 figs. McGraw-Hill Book Company, Inc., New York. 1937. $4.00.

THE author states that this book is the "outgrowth of several years' experience in presenting a one-semester course dealing with economic plants." He has expressed an aim to give the student, through a knowledge of industrial, medicinal and edible plants, a broader outlook, greater interests in the world about him and a realization of the importance of plants and plant products to mankind. Nine chapters deal with such industrial plants and plant products as fibers, wood, cork, tanning and dye materials, rubber and other latex products, gums and resins, essential oils, fatty oils and waxes and sugars, starches and cellulose products. Two chapters consider medicinal plants, fumitories and masticatories. Seven chapters discuss the history and nature of food plants, cereals, legumes and nuts, vegetables and fruits, both of temperate and tropical regions. There are two chapters on food adjuncts, including spices and other flavoring materials, beverage plants and beverages. A systematic list of species discussed, a bibliography and an index constitute the appendix. Books of this sort serve a good purpose, and the author has succeeded well in carrying out the aims expressed in the preface.

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Herbals, Their Origin and Evolution. A chapter in the history of botany, 1470–1670. By AGNES ARBER. 2nd ed. xxiv + 326 pp. 131 figs. 26 plates. Cambridge University Press, Cambridge. 1938. $7.50.

THE revival of interest in herbs and herb gardens makes unusually timely this revised and enlarged edition of Mrs. Arber's book on herbals. These curious mixtures of descriptive botany, gardening, folk-lore, medicine, wood-engraving and even cookery were so highly prized in families fortunate enough to own one that many have come down in good condition to the present time and formerly could be bought at reasonable prices. Their acquisition by institutions and private collectors has made prices soar, and good copies of the classic herbalists have become impossible except to the very wealthy.

Mrs. Arber's book offers more, however, than could be found in any one collection, since it contains excellent reproductions of the more striking of the drawings and woodcuts from a variety of sources, many inaccessible to the ordinary botanist. While nearly all the text figures and plates of the earlier edition have been retained, a few substitutions have been made, and the number has been increased. Much of the text has been rewritten and expanded. An appendix lists chronologically the more important herbals and botanical works published during the period covered.

Even libraries and individuals owning a number of herbals will find in this book valuable sidelights on the development of descriptive botany in the comparative chapters on the various countries and in the attractive and accurate accounts of the herbalists themselves.

B. F. LUTMAN
UNIVERSITY OF VERMONT

[1] A. H. Curtis, "Textbook of Gynecology," pp. 111, 404. W. B. Saunders Company, 1938.

[2] H. Dam and F. Schonheyder, *Biochem. Jour.*, 30: 897, 1936.

[3] A. L. Lichtman and W. H. Chambers, SCIENCE, 88: 358, 1938.

Introduction to Plant Pathology. By FREDERICK DEFOREST HEALD. xi + 579 pp. 200 figs. McGraw-Hill Book Company, New York and London. 1937. $4.00.

DR. HEALD would be the first to insist that there is little point in a review which is wholly laudatory, or merely descriptive, yet I am unable to write any other sort regarding his latest book. This volume is the work of a master of lucid style with long experience in preparing texts, who is recognized as one of the best teachers of plant pathology in this country.

Diseases caused by parasites still get the largest share of space, a little more than 250 pages. The nonparasitic and virus diseases take up about 150. The sixty pages given to plant disease prevention and control include a number of recently discovered and little known methods, while the fifty introductory pages give material of general and vital interest to students who are not specifically interested in agriculture or, for that matter, in plant pathology, but merely in human affairs. If forced to indicate a change, I would suggest the omission of the section on "Methods," leaving that subject for the more detailed manuals.

Teachers of plant pathology are fortunate to have such a book available, and I suspect there are few of them who do not frequently consult it, even if they do not use it in their classes.

NEIL E. STEVENS

UNIVERSITY OF ILLINOIS

Plant Ecology. By JOHN E. WEAVER and FREDERIC E. CLEMENTS. Second edition. xxii + 601 pp. 271 figs. McGraw-Hill Book Company, New York and London. 1938. $5.00.

THE first edition of this book appeared in 1929. The second revised and enlarged edition appears while the work is still unrivaled in our language. The new edition has 81 more pages, 9 more illustrations and 429 more papers cited in its literature list than the old.

Considerable attention is given to applied ecology, notably conservation. Much new and valuable material is included under the discussion of soil. However, recent advances in the field of atmospheric factors and climatology have received less attention than they deserve. The section on methods of studying vegetation has been augmented somewhat. Without enthusiasm, the frequency-abundance quadrat method is described. Besides other variations of the quadrat, the relict method and pollen analysis also are discussed.

The past decade has seen remarkable advance in the practical use of ecology. In education the condition is less satisfactory. In many of the leading older institutions the subject is not recognized as a discipline nor given attention in introductory biology. Perhaps matters would be helped if such an influential book as this were to approach the difficult problem of vegetation and plant communities in a more tentative spirit. The task of reducing this problem to some order has involved drastic measures which create the impression of a finality that is doubtless far from the thoughts of either author.

PAUL B. SEARS

OBERLIN COLLEGE

Plant Physiology. With reference to the green plant. By EDWIN C. MILLER. Second edition. xxxi + 1201 pp. 39 figs. McGraw-Hill Book Company, New York and London. 1938. $7.50.

ALTHOUGH the chapter headings are the same as in the first edition, much new material has been incorporated. The increase in length is 300 pages, and of these 61 have been added to the chapter on growth; about 20 pages each to the chapters on the cell, loss of water, formation of carbohydrates, nitrogen metabolism, translocation and respiration; less than 10 pages of increase are found in each of the chapters on solutions and membranes, intake of water and solutes, fat metabolism and digestion. The large number of literature references which made the first edition so valuable to teachers, students and those engaged primarily in research work has been doubled in the new edition, so that now approximately 6,500 citations are available. The extraordinary interest in recent years in the subject of growth is shown by the fact that the 250 references that sufficed for the first edition (literature up to 1929–30) have been increased in this edition to approximately 900. New material, or more complete discussions than appeared in the previous edition, will be found on the following topics: cell membrane formation, oxygen supply and root growth, absorption of solutes, minor elements, indications of nutrient deficiencies, drought resistance, autumnal coloration, nitrogen metabolism, latex, cohesion theory of the ascent of sap, translocation (direction, distance, mechanism, tissues involved), respiratory coefficients, composition of air of intercellular spaces, growth-promoting and growth-inhibiting substances, dormancy, ripening, radiation (wave-lengths, x-rays, polarized light), photoperiodism, bioelectric phenomena, effects of various gases and vernalization.

F. E. DENNY

BOYCE THOMPSON INSTITUTE
FOR PLANT RESEARCH

The Structure and Development of the Fungi. By H. C. I. GWYNNE-VAUGHAN and B. BARNES. xvi + 449 pp. 309 figs. Second and revised edition. The University Press, Cambridge. 1937. $5.50.

THE first 48 pages deal with the general characters

of the fungi, such as structure, physiology and relationships to other organisms. This introductory survey is the most interesting and valuable part of the book, bringing to one's attention much important work that has been omitted from other similar books. A brief discussion of the Monads, the possible representatives of the ancestral stock of the fungi, is given. The Myxomycetes and Plasmodiophorales are excluded from the fungi and are unfortunately too briefly discussed.

Then follows a morphological and cytological discussion of the fungi from the Phycomycetes through the Basidiomycetes. The Fungi Imperfecti are dismissed in two pages. The final chapter of twenty pages is on mycological technique, presenting valuable information on the isolation, culturing and staining of fungi. The list of literature includes well over 1,000 titles.

The authors have the knack of saying much in a few words, and it is therefore unfortunate that so many valuable investigations, instead of being summarized, are passed over entirely or merely mentioned. For example, in the preface the authors emphasize the importance of flagellation as a guide to the interrelationships of the Phycomycetes and yet fail to take full advantage of both old and new researches on this very subject.

It must be remembered, however, that the book is addressed to the student rather than to the investigator, and as such a book it will fill an important need in mycology classes.

JOHN N. COUCH
UNIVERSITY OF NORTH CAROLINA

The Structure of Economic Plants. By HERMAN E. HAYWARD. x + 674 pp. 340 figs. The Macmillan Company, New York. 1938. $4.90.

THIS book, "an outgrowth of courses in plant anatomy offered at the University of Chicago since 1927," is most timely and welcome. For a long time those interested in applied botany, research workers and students, have had a need for a work which would assemble the investigations relating to the structure and developmental anatomy of important economic plants. This work may serve to point out that the student may learn fundamental anatomy from a consideration of such plants as onion or radish as well as from a study of little-known and relatively unimportant species.

The book is organized in two parts, the first of four chapters dealing with general plant anatomy, the second with the structure of a selected number of economic plants. Part I, including cells and tissues and their development, the anatomy of the root, the anatomy of the shoot and the anatomy of the flower and fruit, is sufficiently comprehensive to make the book generally useful.

Part II considers the structure and developmental anatomy of *Zea mays, Triticum* spp., *Allium cepa, Cannabis sativa, Beta vulgaris, Raphanus sativus, Medicago sativa, Pisum sativum, Linum usitatissimum, Gossypium* spp., *Apium graveolens, Ipomoea batatus, Solanum tuberosum, Lycopersicum esculentum, Cucurbita* spp. and *Lactuca sativa.* The author states that "the principal criteria determining the selection were the economic importance of the plant, its suitability as a representative of the family to which it belongs, and the intricacy of its anatomical and morphological detail." In addition to the numerous original illustrations, others have been selected from various special studies; nearly all are well-labelled. Citations of the more important literature conclude each chapter. A glossary "defining the terms in the sense in which they are used in this work" is appended. It is gratifying to know that the author contemplates a second volume which will deal more especially with important fruit crops. The present volume is a distinct contribution, meeting a long-felt need in the field of applied botany.

W. W. ROBBINS
UNIVERSITY OF CALIFORNIA

General Plant Physiology. By E. C. BARTON WRIGHT. Foreword by Sir F. Gowland Hopkins. 539 pages, 44 figs. P. Blakiston's Sons and Company, Philadelphia. 1938. $4.50.

THE reviewer considers this book to be one of the better texts in plant physiology. Conservative in the treatment of many topics, the emphasis on the various aspects of plant physiology is well placed, and the student who masters such a presentation will receive sound training upon which to evaluate more controversial work. The chemical aspects of physiology receive the greater attention; the discussions of carbohydrates and fats are especially well done. Preliminary training in organic chemistry is a necessary prerequisite for an understanding of a large part of the material discussed. Effective use is made of curves, diagrams and structural formulae.

There is a tendency to give greater prominence to English contributors to plant physiology, as might be expected, and not every one would agree with the author's judgment that Mason and Maskell's and Mason and Phillis' studies on translocation in the cotton plant "represent . . . one of the most brilliant series of advances that has been made in plant physiology," in spite of the extensive and thorough work involved in those studies. Some will object also to statements that all living things are capable of movement, that metabolism is the main concern of plant physiology, and some will criticize the emphasis placed on the gas exchange in respiration rather than the energy relations. Others will be disappointed to find that vapor pressure receives little attention in the con-

sideration of transpiration. To still others, however, it will be a pleasure to find that osmosis is treated as diffusion through a membrane and that it is not limited to the diffusion of water through a semi-permeable membrane, as some American authors are inclined to treat it. The book is divided into three parts—Part I, "General Physiology of the Cell"; Part II, "Metabolism"; and Part III, "Growth, Reproduction and Irritability." That such a division is not entirely satisfactory is shown by the inclusion of transpiration and ascent of sap in Part I, "General Physiology of the Cell," and transport of solutes in Part II, "Metabolism."

A few criticisms selected from many pages may give an impression that much of the book is regarded unfavorably. Such is not the intent, however, as is indicated by the early portion of this review.

The press work and binding are excellent.

WILLIAM J. ROBBINS
NEW YORK BOTANICAL GARDEN

A Bibliography of Eastern Asiatic Botany. By ELMER D. MERRILL and EGBERT H. WALKER. xlii + 719 pp. Jamaica Plain: Arnold Arboretum. 1938. $12.50.

IN every field, good bibliographies are keys to literature that vastly enhance its usefulness. Perhaps the time may come when the best bibliographies will cover the fields where such works are most needed, but up to the present time most bibliographers have chosen their own fields, and each has recorded the literature of the subjects in which he was most deeply interested.

And so it has happened that this fine bibliography, remarkably complete and accurately compiled, deals with the plant life of eastern Asia, with which both authors have long concerned themselves. It may be said in justification of this undertaking that, unless checked by the present unsettled conditions in that part of the world, our knowledge of the Asiatic flora is entering upon an era of great expansion, and the existence of a record such as this of what has already been done may prevent duplication of effort.

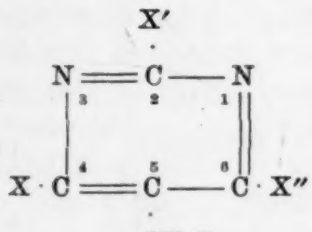
"Eastern Asia," as the term is here used, "comprises China, Japan, Formosa, Korea, Manchuria, Mongolia, Tibet, and eastern and southern Siberia," and works are included relating to the flora of adjacent regions, when these have an important bearing on that of the region mentioned. There are more than 21,000 author-entries, including references to more than 1,200 serials; these have been checked to the original sources whenever possible, and an effort has been made to correct erroneous statements of dates of publication, unless this would involve unwarrantably extensive investigation. The troublesome cases arising from the many authors' names and the titles in Russian, Japanese and Chinese characters have been handled in an eminently satisfactory manner, and there are separate lists of Chinese and Japanese serials and of Chinese and Japanese authors. There are also classified subject-indexes, filling about 125 of the quarto pages. The clerical and typographical errors are remarkably few for a work of this character. In short, the volume is a permanent testimonial to the diligence and scholarship of its authors and will long remain a standard work of bibliographic reference.

JOHN H. BARNHART
NEW YORK BOTANICAL GARDEN

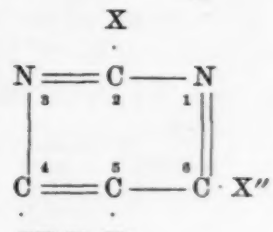
SPECIAL ARTICLES

VITAMIN RESEARCH

A BIOCHEMICAL research program that is receiving attention in the Sterling Chemistry Laboratory at the present time calls for the development of practical methods of synthesizing primary halides of the pyrimidine type, corresponding to the organic structure expressed by formula I. Primary, pyrimidine halides of such constitution are difficult to prepare, and function as necessary intermediates in the synthesis of vitamin principles of the vitamin B_1 type. For example, the recently devised method of synthesizing the anti-neuritic vitamin, *thiamin* (V), is based on the fact that a pyrimidine halide represented by formula III couples



I



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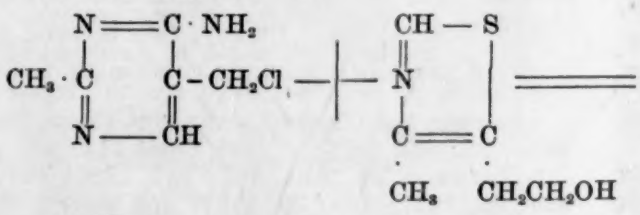
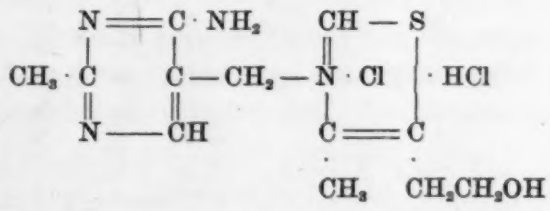
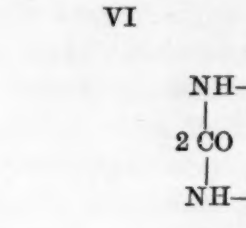


III

IV



V



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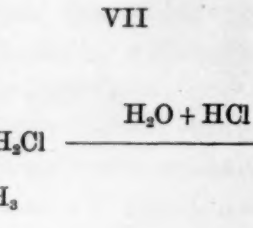


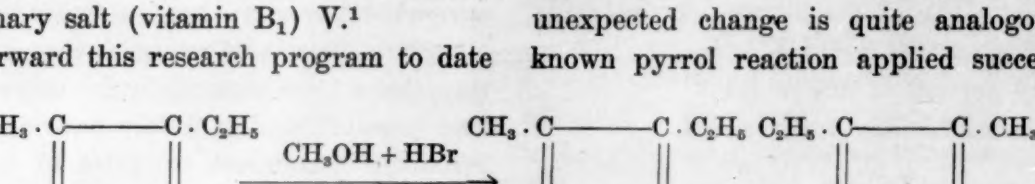
VII

with a specific thiazole (IV) to form the naturally occurring quaternary salt (vitamin B_1) V.[1]

In carrying forward this research program to date our efforts have been confined to the development of new methods of synthesis and to the study of the chemical properties of pyrimidine halides of the uracil type. We now desire to report a recent discovery which reveals a striking difference in chemical behavior between the two isomeric pyrimidine halides expressed by formulas VI and VII. Here we are dealing with primary halide groupings substituted in the 4- and 5-positions, respectively, of the 2,6-dioxy-pyrimidine molecule.

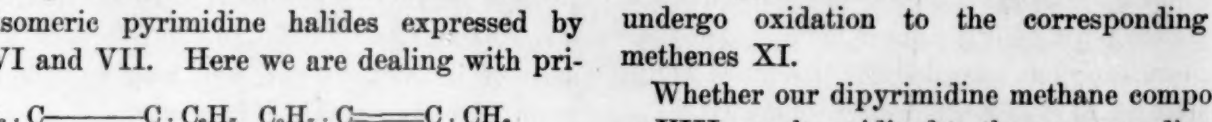
It was the senior author's experience during his earlier researches on the synthesis of simple nucleoside constructions in 1913–1915 that pyrimidine halides of the type VI are extremely stable and are very resistant to hydrolysis. For example, it was shown that both 4-chloromethyluracil and the pyrimidine halide VI can be heated with concentrated hydrochloric acid at 125–130 without alteration.[2] This behavior is in marked contrast to that observed with the halide represented by formula VII.

This pyrimidine VII is very unstable when digested with alcohol or water and can be converted practically quantitatively into the dipyrimidine methane derivative



VII VIII

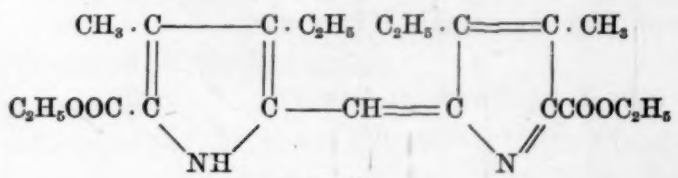
VIII upon treatment with hydrochloric acid. This unexpected change is quite analogous to the well-known pyrrol reaction applied successfully by Professor Hans Fischer and his coworkers in many cases for the preparation of dipyrrol methanes; and which is illustrated by the following reaction employed for the preparation of the dipyrrol methane derivative X.[3] These dipyrrol methane compounds such as X easily undergo oxidation to the corresponding dipyrrol methenes XI.



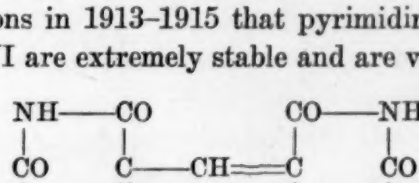
IX X

Whether our dipyrimidine methane compounds such as VIII may be oxidized to the corresponding unknown dipyrimidine methene derivatives such as XII remains to be determined.

A complete account of the results of this pyrimidine investigation will be presented in future publications from this laboratory.



XI



XII

TREAT B. JOHNSON
MARGARET M. ENDICOTT

YALE UNIVERSITY

THE PREPARATION OF GLUTATHIONE CONTAINING RADIOACTIVE SULFUR

ARTIFICIAL radioactive elements are usually produced as the free isotopes of ordinary elements and may be used in the preparation of compounds suitable for study. The present work was undertaken in order to find a method of obtaining radioactive glutathione to be used later in the study of certain phases of sulfur metabolism in rats. Briefly, this method consisted in growing yeast in a medium containing radioactive sul-

[1] Williams and Cline, *Jour. Am. Chem. Soc.*, 58: 1063, 1504, 1936; 59: 216, 1937; Cline, Williams and Finkelstein, 59: 1052, 1937.

[2] Johnson and Chernoff, *Jour. Am. Chem. Soc.*, 36: 1742, 1914; 35: 585, 1913; *J. Biol. Chem.*, 14: 307, 1913.

[3] Fischer *et. al.*, Ann. 447: 137, 1926; 448: 199, 1926; 459: 85, 1927; 486: 39, 1931; and several other publications.

fur in a form which was easily assimilated by the yeast in its growth. Subsequently glutathione was extracted from the yeast so obtained and found to be radioactive. The technique developed is probably applicable to the preparation of other compounds.

The strain of yeast used was *Saccharomyces cerevisiae,* Frohberg type,[1] which was known to produce considerable quantities of glutathione. The medium used was an adaptation of that employed by Sugata and Koch.[2] They found that sulfur in the form of a sulfate is a true nutrient for yeast and is more easily assimilated than is sulfur in an organic form. In view of this the radioactive sulfur was converted into sulfate and added to the medium in that form. The medium had the following composition:

Refined cane sugar	100.00	grams	per	liter
Asparagine	1.5	"	"	"
Mono ammonium phosphate	3.0	"	"	"
Mono potassium phosphate	2.0	"	"	"
Magnesium chloride	0.25	"	"	"
Magnesium sulfate (radioactive)	0.25	"	"	"

It was found necessary to add bios for good growth; beer wort or a yeast extract made by boiling 50 grams of dried yeast in 500 cc of distilled water for 30 minutes proved to be a convenient source. Unfortuately, analysis of these bios preparations showed appreciable amounts of sulfur to be present. When a 1 per cent. concentration of these extracts, which was found to be a favorable concentration for growth, was used, the amount of sulfur added to the medium in the bios-containing extract was approximately the same as the amount of sulfur, in the form of magnesium sulfate, in the medium. This tended to decrease the activity of the final product. Determinations of the variation of glutathione content with the growth period of the yeast were made by the specific glyoxalase method of Woodward.[3] Maximum glutathione yield was reached after three days, which period of time was therefore chosen as the growth period.

The radioactive sulfur used in this work was prepared by bombardment of roll sulfur by 10 Mev deuterons accelerated by the cyclotron of this laboratory. Under this treatment a portion of the S^{34} is converted into S^{35} according to the reaction

$$_{16}S^{34} + {}_1H^2 \rightarrow {}_{16}S^{35} + {}_1H^1$$

S^{35} emits beta rays of about 0.107 Mev energy and has a half life of about 88 days.[4] The sulfur was converted into magnesium sulfate by oxidation in a stream of oxygen in the presence of platinum catalysts at 600° C. The SO_3 vapors formed were led into an absorption chamber containing 5 per cent. solution of H_2O_2 and an excess of magnesium oxide, resulting in the formation of magnesium sulfate. The excess of magnesium oxide was filtered out and the solution freed from H_2O_2 by boiling.

Under the bombardment a part of the sulfur was converted into other radioactive elements, principally radioactive phosphorus, which, while not interfering with the growth of the yeast, had to be eliminated when activity measurements were made. When such measurements were to be made, the sulfur was precipitated from the magnesium sulfate solution as barium sulfate, washed thoroughly and dried to constant weight. A portion was weighed in a small nickel boat, a few drops of water added to form a suspension, which was evaporated to dryness to form a thin uniform layer. A drop of egg albumin or gum acacia added to the suspension before evaporation prevented accidental loss of the barium sulfate while measurements were being made.

Since the thin walls of the usual type Geiger counter absorb much of such weak radiation as is emitted by radioactive sulfur, activity measurements were made with a specially designed tube. The nickel boat, containing the sulfur sample, was placed in a side arm which did not permit the rays to reach the counter proper. The tube was evacuated to the desired pressure and the background count taken. The sample was then moved into place with a magnet and the count taken in the usual manner.

After the yeast had grown for three days it was separated from the medium by centrifuging and the glutathione isolated as the highly specific cuprous derivative, by a modification of Pirie's[5] method. Thirty grams of moist yeast containing approximately 30 milligrams of reduced glutathione yielded 20 milligrams of cuprous salt exhibiting the silvery sheen characteristic of this compound in aqueous solution. A portion of the cuprous salt was freed from copper by means of H_2S; the resulting solution was found to be capable of activating the enzyme glyoxalase, thus establishing the presence of free glutathione in the solution. The remainder of the cuprous salt was repeatedly washed by centrifuging until the washings gave no further test for sulfate. A sample of this material, containing 0.3 mg sulfur, gave a count of 150 per minute in the Geiger counter. Another portion, containing 0.25 mg sulfur, was ignited and the sulfate formed precipitated as barium sulfate. This gave a count of 100 per minute. Due to the self-absorption of the beta rays within the different samples, these measurements are only approximately quantitative.

This work would not have been possible without the help and encouragement of Dr. Ellice McDonald, director of the laboratories, and of various members of

[1] *Saccharomyces cerevisiae,* Frohberg type, was kindly furnished by the Fleischmann laboratories.

[2] H. Sugata and F. Koch, *Plant Physiol.,* 1: 337, 1935.

[3] G. E. Woodward, *Jour. Biol. Chem.,* 109: 1, 1933.

[4] W. F. Libby and D. D. Lee, *Phys. Rev.,* 55: 245, February 1, 1939.

[5] N. W. Pirie, *Biochem. Jour.,* 24: 51, 1930.

the staff, and we take pleasure in thanking them. Our thanks are especially due to Drs. A. J. Allen, M. B. Sampson and W. Danforth for the preparation of the radioactive sulfur and to Dr. E. F. Schroeder and Miss G. E. Woodward for the isolation and identification of the glutathione.

RACHEL G. FRANKLIN
BIOCHEMICAL RESEARCH FOUNDATION OF
THE FRANKLIN INSTITUTE, PHILADELPHIA

CRYSTALLINE HORSE LIVER CATALASE

ONE of us (O. D. F.) observed that after dialysis for three weeks near the isoelectric point, a solution of horse liver catalase prepared by the method of Agner[1] deposited a small amount of active crystalline material. Not enough of this precipitate was obtained for accurate analysis.

Later, by modifying the method for preparing crystalline beef liver catalase[2] we obtained crystalline horse liver catalase in good yield. The crystals are in the form of very fine needles. After preliminary purification, including fractional precipitation with dioxane, crystallization was induced by slow addition of ammonium sulfate to the properly buffered catalase in a solution containing 3.0 per cent. of dioxane. Catalase crystals have been obtained also from preparations made by Agner's directions up to the point where the material is adsorbed by passing it through a column of calcium phosphate.

A sample of once-recrystallized horse liver catalase has been found to have a *Kat. f.* of 50 to 55 thousand, which is of the order of magnitude of that of the best preparation of Agner. We do not think that the material is yet entirely purified, since the content of iron is 0.2 per cent. instead of 0.09, which would correspond to the hemin iron. It is possible that our material was contaminated with a small amount of a protein high in iron which was observed during the preparation of the catalase crystals, and which is probably identical with the ferritin of Laufberger.[3]

The percentage of hemin, determined by colorimetry and by analysis for hemin iron, is about 0.9, which agrees with the claim of Stern and Wyckoff[4] that horse liver catalase contains about 0.1 per cent. of hematin.

Treatment of the once-recrystallized horse liver catalase with acetone and HCl split off the hemin which dissolved in the acetone. Evaporation of the acetone caused the hemin to precipitate, leaving a small part of the non-hemin iron in the supernatant liquid. Most of the non-hemin iron was in the protein residue.

Our analysis of the sample of once-recrystallized horse liver catalase showed that the copper content was practically negligible, contrary to the finding of Agner that the copper content of horse liver catalase is high enough to be of possible significance.

ALEXANDER L. DOUNCE
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DEPARTMENT OF PHYSIOLOGY AND
BIOCHEMISTRY, MEDICAL COLLEGE,
CORNELL UNIVERSITY

INFECTION OF CHICKS AND CHICK EMBRYOS WITH RABIES[1]

IT is the purpose of this communication to present a preliminary report of observations made on chicks and chick embryos inoculated with rabies virus. These investigations were undertaken in order to study the lesions produced in this species and also to determine the changes which might take place in the virus following its adaptation to this unnatural host.

Rabid dog brain passed once through mice was the source of the virus used in this work. Histologically, this dog brain and the mouse-passage brain showed typical Negri bodies. The inoculum consisted of 0.03 cc of 10 per cent. brain emulsion.

Intracerebral inoculation of day-old chicks was followed by signs of rabies after 19 days on the first passage, and 4 passages did not reduce this period appreciably. There was considerable variation in the incubation period and also in the duration of the disease; some animals died within 2 days after the first signs of the disease, while others showed definite paralysis for 2 weeks before death. All these chicks went through a stage of excitement before the onset of flaccid paralysis.

At autopsy no gross lesions were demonstrable. Microscopic examination of brains and cords revealed many Negri bodies, some quite small, others huge. Non-specific changes in the form of acute necrosis of ganglion cells and massive perivascular accumulations of lymphocytes and large mononuclear phagocytes were present throughout the central nervous system.

Portions of brain from the 4th intracerebral passage in chicks were ground and emulsified and 0.03 cc were inoculated intracerebrally into 13-day-old chick embryos. The eggs were opened and the embryos were inoculated according to the technique which had been developed in this laboratory. After 4 days one embryo was sacrificed and its brain was inoculated into the brains of other embryos; subsequent passages have been made every 6 or 7 days, and the virus is now in its twelfth generation.

We have not allowed any chick embryos inoculated by the intracerebral route to hatch. Several embryos inoculated by this route have died between the sixth

1 K. Agner, *Biochem. Jour.*, 32: 1702, 1938.
2 J. B. Sumner and A. L. Dounce, *Jour. Biol. Chem.*, 121: 417, 1937.
3 V. Laufberger, *Bull. Soc. Chim. Biol.*, 19: 1575, 1937.
4 K. G. Stern and R. W. G. Wyckoff, *Jour. Biol. Chem.*, 124: 573, 1938.

1 Aided by grants from the John and Mary R. Markle Foundation.

and eighth day after inoculation; otherwise there has been no definite clinical evidence of rabies. Most of the embryos appeared vigorous and it is believed that they would have hatched if they had not been sacrificed.

Microscopic examination of brains and cords of embryos killed on the sixth or seventh day revealed an enormous number of Negri bodies and acute neuronal necrosis. Evidence of inflammation was never very impressive, but there was some phagocytosis of necrotic ganglion cells in the cord.

Sixth passage virus was inoculated in 0.03 cc volume in the brain, in the thigh, on the chorio-allantoic membrane, in the eye and in the amnion of separate embryos. Six days following inoculation two embryos inoculated by each route were killed and fixed for study. Histological examination of embryos inoculated intracerebrally and intra-ocularly showed Negri bodies throughout the central nervous system, in the neurones of the retina and in some peripheral ganglia. Negri bodies were found only in embryos inoculated in the brain or in the eye. Furthermore, two embryos inoculated on the chorio-allantoic membrane were allowed to hatch, and neither one showed any clinical evidence of rabies during a ten-day period of observation.[2]

Experiments are being performed at present to determine the virus content of various organs and tissues of embryos inoculated by various routes, the biological changes which may have taken place in the virus following adaptation to this new host and the histological evidence of change in tropism of the virus.

The work at present indicates that the chick embryo brain is an ideal medium for the propagation of rabies virus. This method of virus culture has the advantage over *in vitro* methods in that one is able to study the pathological changes induced in the embryos by the multiplication of virus. We feel that chick embryo brain provides a richer source of rabies virus than has been obtainable in the past and that for this reason alone it may be of value in the preparation of a vaccine.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

USE OF LUMINOUS PAINT FOR OBSERVATION OF ANIMAL MOVEMENTS IN THE DARK

THE behavior of animals in the dark is often a matter of interest, but one which is difficult to study. It might be of value, therefore, to report a technique involving the use of luminous paint. This method was developed as a means for observing the swimming position of the brine shrimp, *Artemia,* when placed in total darkness.

An adult *Artemia* is laid out on a glass slide and carefully dried with filter paper. A drop of "Durofix"[1] is then placed in a watch glass, diluted with acetone, and mixed with luminous paint powder. The mixture is transferred to the surface of the animal on the tip of a suitable needle. After about ten minutes small traces of moisture are applied to those parts of the animal's body which are not too near the paint. Finally more moisture is added and the slide is carefully lowered into a jar of water. Practice is required to determine the best mixture for good adhesion. In successful cases the paint remains attached until the next moult and the animals live for many days.

The blobs of paint affixed to *Artemia* have been usually half a millimeter or less in diameter. Tests have shown that only the non-radio-active paints are satisfactory for such small spots. A paint supplied by Harrington Brothers, of London, gives a glow clearly visible to dark-accustomed eyes for fifteen minutes after daylight activation. Larger spots glow for a longer time.

With animals not so small as *Artemia* radio-active paints would be more useful. The glow which they give is continuous, but unfortunately less bright than can be obtained by daylight activation. The United States Radium Corporation of New York supply a paint which I have tested in dots of various sizes, prepared in the manner outlined above. The smallest spots glowed too faintly to be seen. Larger spots, one millimeter or more in diameter, gave good results.

JOHN H. LOCHHEAD
THE BIOLOGICAL LABORATORIES,
HARVARD UNIVERSITY

[1] A waterproof, transparent adhesive, manufactured by the Rawlplug Co., Ltd., London.

QUANTITATIVE TRANSFER OF AQUEOUS SOLUTIONS

IN the study of cell metabolism employing either the Barcroft-Warburg respirometer or the reduction method of Tünberg, it is often essential for the accuracy of the determination that the total volume of "test solution" contained in the side-arm of the vessel be transferred quantitatively to the cell suspension. In order to eliminate the factor of drainage a non-wettable surface is essential. For this purpose a coating of ferric stearate has proven of great utility, far sur-

[2] I. J. Kligler and H. Bernkopf, *Proceedings of the Soc. for Exper. Biol. and Med.*, Vol. 39, No. 1, p. 212, October, 1938.

passing paraffin, due to its negligible volume, ease of application and absence of contaminated areas on which a portion of the solution may remain. It is applied by filling the vessel with a one-quarter saturated solution of ferric stearate in benzene, draining, and allowing the solvent to evaporate. This leaves a very thin coating of ferric stearate. The hydrophobic surface so formed is not attacked by thirty minutes' exposure to 0.1: N HCl, 0.1 N NaOH, saturated NaCl, petroleum ether, chloroform or ether. Further it does not adsorb methylene blue as does glass, nor interfere either in respiration or dye reduction in any of the systems so far studied. Ferric stearate may also advantageously replace paraffin in coating micro-capillary pipettes, as employed by Wigglesworth[1] in the micro-estimation of chloride. The sample of ferric stearate employed was prepared by mixing ferric chloride with a warm, concentrated aqueous solution of sodium stearate, followed by filtration and washing (*c.f.* Langmuir and Schaefer[2]).

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AMPHIBIAN GAMETES AS BIOLOGICAL TEST MATERIAL

BIOLOGICAL material suitable for testing physical or chemical variables has not been abundant, dependable nor constantly available. Through the discovery that hibernating frogs can be stimulated by the anterior pituitary hormone to release their gametes, there is now available material which may be the answer to the experimental biologist's needs. Between September and March female frogs can be induced to provide upwards of 2,000 eggs (each) at the identical stage of maturation and 24 hours after pituitary stimulation. The eggs may be stripped from the female as needed, in lots of from 50 to 100, or in case of experiments where quantitative data are desired, entire uteri may be tied off as sacks full of eggs and removed from the body. The eggs from one uterus may be used for control as against the eggs of the other uterus, which are subjected to the experimental variables. The frog testes may either be dissected in Holtfreter's modification of amphibian Ringer's (diluted to 10 per cent.) or the male may be similarly stimulated by hormone treatment to release the spermatozoa into its seminal vesicles. Uniform and concentrated suspensions of spermatozoa may be kept for many hours without loss of inseminating powers. This period is shortened with dilution and high temperatures and may be extended if the suspensions are kept at refrigerator temperatures.

[1] V. B. Wigglesworth, *Biochem. Jour.*, 31: 1719, 1937.
[2] I. Langmuir and V. Schaefer, *Jour. Am. Chem. Soc.*, 59: 2400, 1937.

In some recent investigations with both low and high voltage x-radiation, embryos from radiated gametes have shown consistent and quite uniform results. With carefully controlled x-radiation of either sperm or eggs, many of the earlier predictions of Hertwig and of Bardeen have been confirmed. There are, however, many new and biologically significant aspects of this radiation problem, which have been revealed by our modern precision equipment and this newly available biological material. It has been impossible, for instance, to render immotile frog spermatozoa with high voltage radiation even up to 120,000 r., although some abnormal embryos appear when the spermatozoa receive as little as 25 r. Early cleavage of eggs fertilized by radiated sperm is perfectly normal in both rate and pattern. There is, however, some evidence that near 10,000 r. the sperm nucleus is sufficiently damaged as to prevent neurulation, but eggs inseminated with spermatozoa which have been exposed to upwards of 30,000 r. will result in quite normal-appearing tadpoles, which may, however, be haploids. Both frog's sperm and eggs are being used to test, from a biological point of view, the qualitative difference between the soft and the hard x-rays.

The details of these radiation experiments will be reported elsewhere, but it is the purpose of this note to call attention to this extremely abundant and dependable biological test material which can be used along the lines of genetics, cytology, cell physiology and embryology.

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